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*A scientific recreation—the extent and accuracy of our measurable concepts.*[1] HARVEY L. CURTIS, National Bureau of Standards.

Before giving consideration to the subject I have chosen for this evening's address, I wish to assure members of the Washington Academy of Sciences that I am not unmindful of the fact that this nation is in the midst of a war which demands all our intellectual acumen as well as our physical stamina. It would seem fitting that the address of the retiring president should deal with some of the problems that are concerned with the war effort. However, any scientific topic connected with the war could not be adequately treated because of restrictions imposed by military necessity. That would limit a discourse involving the war effort to an emotional subject that would either stimulate our egotism by praising our accomplishments or would raise our morale by appealing to our sense of responsibility as leaders in science. I am convinced that no pronouncements of mine would appreciably influence your morale. Concerning egotism, I prefer to make no comments. I have, therefore, chosen a subject that has no relation to this war. My purpose is to furnish a little recreation to those who are scientifically minded.

The description of the universe in which we live is facilitated by our ability to evaluate numerically many of our concepts concerning it. Thus a length can be expressed numerically in feet, a mass in kilograms, a time in hours, and other quantities in terms of appropriate units. The concepts that can be expressed by reference to a single unit are the simplest of those which are recognized by human beings. Other concepts, such as heat, light, and sound, require for their evaluation two or more numbers, each associated with its own unit, and the relationship between these numbers may be expressed by means of a mathematical equation of some complexity. Still other concepts such as odors, emotions, and physical pain can not yet be numerically evaluated. This address will be concerned only with the simplest concepts, so that any quantity to be discussed can be completely evaluated by a single number when associated with a specific unit.

The accuracy with which a given object or quantity may be measured can be expressed numerically. Thus the equatorial diameter of the earth, a distance of more than 12½ million meters, has now been measured with an accuracy of about 1 part in 300,000. The uncertainty in the value of the diameter is, in this case, solely the result of errors in the experimental determination, since both the standard meter and the equatorial diameter are definite to a much higher degree of accuracy. However, if our standard of length were a wooden meter stick, which might change in length from day to day by a part in a thousand, then the accuracy of determining the equatorial diameter would be limited by the definiteness of the standard and might be 5,000 or 10,000 meters instead of the experimental error of 50 meters. It is the aim of all standardizing laboratories so to maintain their fundamental standards that the accuracy of any measurement involving them will depend either on the experimental method used in making the measurement or on the indefiniteness of the object or quantity to be measured, and not on the definiteness of the standard.

The accuracy that can be attained in measuring a quantity depends on its magnitude. A very large or a very small distance,

[1] Address of the Retiring President of the Washington Academy of Sciences delivered at the 317th meeting of the Academy, February 18, 1943. Received March 15, 1943.

or mass, or time, or any other quantity can not be measured with as much accuracy as one of intermediate value. It is of interest to trace the accuracy of measurement in a few of our concepts throughout their entire range.

Another interesting feature of our simple concepts is the extent of their range. The evaluation of the range of any concept requires that the largest and smallest object or quantity of this concept be measured in terms of the same unit. Then the extent of the concept may be taken as the ratio of the value for the largest known object or quantity to the value of the smallest. The measurements must be in terms of the same unit, but the extent of any concept is independent of the unit used in making the measurements.

Our evening recreation will therefore consist in considering the accuracy of measurement of various physical quantities throughout their entire range and in giving an estimate of the extent of the range of the same quantities. For each of the physical quantities considered there have been selected a number of familiar objects, which range in size from the smallest to the largest for that quantity. For each physical quantity there has been prepared a chart showing the relationship between the size of an object and the accuracy with which it can be measured. A comparison of the charts will show interesting similarities and differences between the quantities.

The three basic quantities in our system of physical measurements are length, mass, and time. Each can be measured over a wide range. Also, the accuracy with which measurements can be made in every part of the range of each is known. Hence, they have certain features in common. A logarithmic plot of accuracy of measurements vs. range will be made using the same relative scale for each, so that comparison can be made of the three curves.

The plot of length or distance shown in Fig. 1 has for its basic ordinate the meter and for its other ordinates multiples or submultiples of the meter. The abscissas are the accuracy of measurement. The scale of distance extends both below and above the unit line, each step representing a factor of 1,000. The scale of accuracy, the abscissa, which has for its unit line one part in one, extends in the positive direction only; each step representing a factor of 10.

The distances indicated on the chart and the accuracy with which they can be measured will now be considered in detail. The object corresponding to the unit ordinate line is the standard meter bar. Two meter bars can be compared with an accuracy of a part in 10 million, or perhaps under very favorable conditions to a part in 30 million. One can appreciate the attainable accuracy by noting that the error in comparing two meter bars is about one-twentieth of the diameter of a fiber of spider silk.

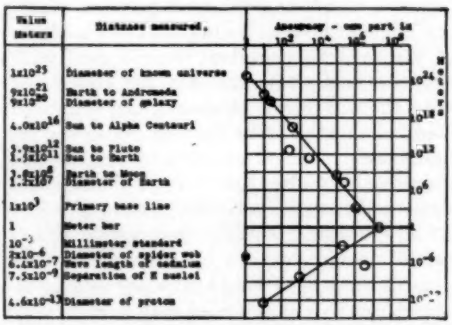


FIG. 1.—The accuracy of measurements of length.

The base line used in primary triangulation, usually a kilometer, can be measured with an accuracy of a millimeter, or a part in a million. The diameter of the earth, about 12 million meters, is known with an accuracy of only a part in 300,000. The larger distances are all astronomical. The accuracy decreases as the distance increases. The values for the accuracy both in this chart and those to follow were, for the most part, either obtained from published data or have been supplied by men experienced in the different fields. In only a few cases is the author's judgment involved.

The greatest distance that can be measured is the diameter of the known universe. The distance to the farthest observed nebula is considered to be of the order of 500 million light years. Assuming this to be the radius of our known universe, the diameter is $10^{25}$ meters. The 200-inch telescope is expected to double this.

For distances less than a meter, which are plotted below the unit line, the accuracy decreases rapidly as the measured distance becomes smaller. For millimeter standards the accuracy has dropped to a part in a few hundred thousand. The distance between the nuclei of a hydrogen molecule is known only to a part in a thousand, while the diameter of a proton, the smallest known object, is known only to 10 per cent.

Exceptions to the uniform decrease in accuracy with decrease in size are the wave lengths of light. The universally accepted standard is the wave length of the red cadmium line. While less than a millionth of a meter in length, this wave length is known with an accuracy of a few parts in 10 million. This accuracy in measurement can be attained because nature places hundreds of thousands of the waves end to end with such fidelity that it is only necessary to measure from the first to the last and count the number of intervening waves.

I have included the diameter of a spider web (a fiber of spider silk) as it is about the smallest distance with which everyone is familiar. However, spider webs vary greatly in diameter, so that one can not assign a definite value to the accuracy of their measurement; hence a dot is placed on the unit line of accuracy at the approximate distance.

This chart shows that, at the present time, length measurements can be made with the greatest accuracy for distances of about 1 meter. This region has not materially changed for several hundred years. Recently interference methods permit the comparison of two end standards which are a decimeter long with about the same accuracy as can be obtained in comparing two line standards which are a meter in length. Thus, while the meter has not been displaced as the length that can be most accurately measured, it is conceivable that it may be when electron microscopes or X-ray interferometers are applied to the measurement of length.

The extent of our concept of length, which is obtained by dividing the largest known length by the smallest, is $2\times10^{37}$. As pointed out when extent was defined, this is not dependent on the unit used in measuring distance. It is a ratio of two like quantities and is therefore dimensionless.

The accuracy with which masses of various magnitudes can be measured is shown in Fig. 2. The coordinates have the same relative values as the preceding chart, each step in the vertical direction representing a factor of 1,000 and each step in the horizontal direction representing a factor of 10. The unit ordinate is 1 kilogram.

Two kilogram standards can be compared with an accuracy a little less than one part in a billion. However, two tons can be compared only to a part in a million, while a battleship can be weighed only to a part in a thousand. The blue whale has been introduced, as members of this species are probably the largest animals that ever inhabited the earth. Since the accuracy of weighing is not available, the weight is indicated by a dot on the unit line of accuracy. A battleship is one of the largest of the terrestrial objects that are ordinarily weighed. The accuracy with which the mass of nearby astronomical objects, such as the moon, earth, and sun, can be determined is largely dependent on the accuracy with which the universal constant of gravitation can be measured. Hence, all have been given the same accuracy. Our galaxy is the largest

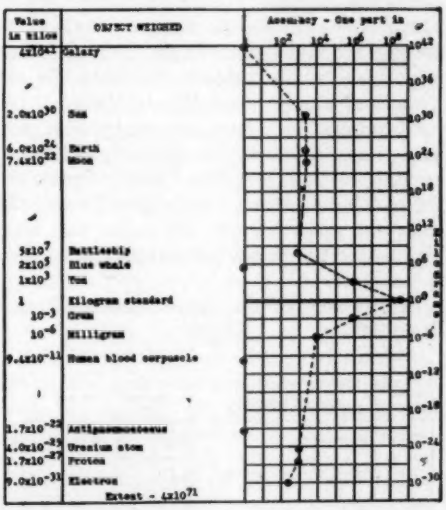


FIG. 2.—The accuracy of measurements of man.

mass considered, being about that of a hundred billion suns. One might include the mass of the known universe, that is probably a hundred billion times that of our galaxy. However, the value is so uncertain that the accuracy scale would have to be extended to negative values of the exponents before it could be represented.

When values less than a kilogram are considered, the accuracy decreases rapidly with decreasing weight. Two living objects may interest the biologists. An antipneumococcus germ or virus is among the smallest of living things. It would require $10^{27}$ of them to weigh as much as a whale. The human blood corpuscle is, on the multiplication scale, about midway between the extremes of living things. The weighing of the very small objects: viz., atoms, protons, and electrons, requires an entirely different technique than employed for ordinary objects. The electron is the object having the smallest mass known. Its value has been determined with an accuracy greater than 1 per cent.

The extent of the measurement of mass is $4 \times 10^{71}$.

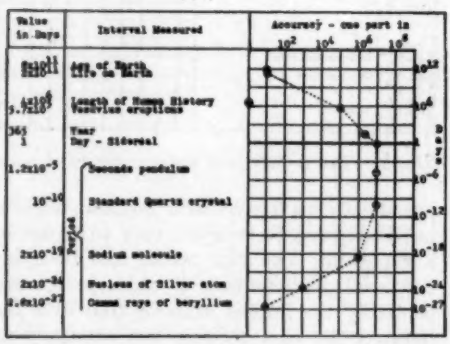


FIG. 3.—The accuracy of measurements of time.

The accuracy with which time intervals can be measured is shown in Fig. 3. The unit ordinate is the day. This is universally used as the standard of time, the second being merely a convenient submultiple of the day. The accuracy of measuring a single day is about a part in 10 million. A single year can be measured to about a part in 3 million. For the next interval I selected the

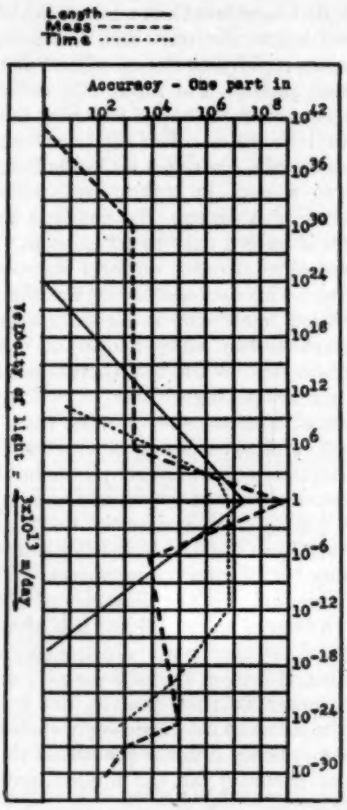


FIG. 4.—Comparison of the accuracy of measurements of length, mass, and time.

time between the two great eruptions of Vesuvius, the first on August 24, 79 A.D., and the second on December 16, 1631. If we consider the changes in calendar that took place, an error of a day or two in establishing these dates is quite probable. The length of human history is too indefinite to warrant more than a dot on the line of unit accuracy. It is now established that the first solid crust still remaining on the earth solidified about 2 billion years, or $8 \times 10^{11}$ days, ago. This, then, is the age of the earth, and it is the oldest point on our time curve that can be definitely established. Life has existed for about one-fourth of that time. There is an uncertainty of at least 10 per cent in both these times.

When times less than a day are considered, the period of the seconds pendulum

and that of a standard quartz crystal can each be determined with the same accuracy as the day itself. The period of the sodium molecule is known with great accuracy, and even that of the nucleus of the silver atom is comparatively well known. The shortest vibration that can be ascribed to a known source is the gamma radiation from beryllium, which is known with an accuracy of about 10 per cent.

The extent of the measurement of time is $3\times10^{38}$.

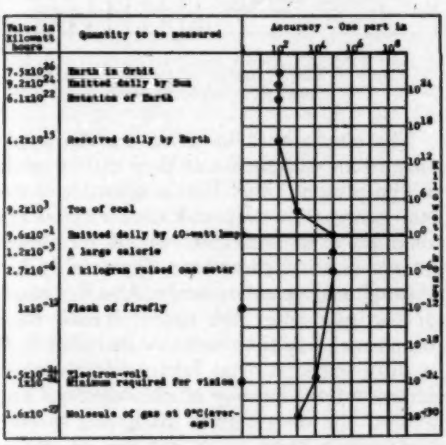


FIG. 5.—The accuracy of measurements of energy.

It is interesting to compare the accuracy curves of the three fundamental quantities of our system of measurements. The curves of the three preceding charts are, therefore, brought together in Fig. 4. An application of these curves is the selection of a suitable base line for measuring the velocity of light. This velocity is about $3\times10^{13}$ m/day. If the length of the base line is from 10 to 100 meters, the time to be measured is between $6\times10^{-11}$ and $6\times10^{-12}$ days. Both this length and this time can be measured with an accuracy of about a part in a million. If a longer base line is chosen the length can not be measured with this accuracy, while if a shorter base line is chosen the accuracy of the time measurement will be decreased.

In each realm of science charts similar to those here presented can be prepared. Outside the fundamental quantities the physical quantity of widest interest is energy. Un-

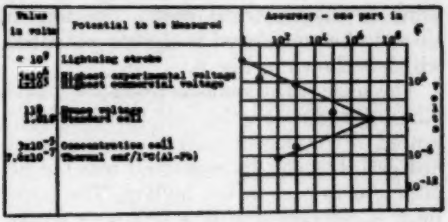


FIG. 6.—The accuracy of measurements of electrical potential.

fortunately, there is no one unit of energy that is regularly used in all fields where measurements of energy are made. I have chosen to take the kilowatt-hour as the basic unit in preparing the chart in Fig. 5. Nearly every adult has some feeling for this unit because it appears on all electric bills. It may be given some semblance of reality by noting that the electrical energy converted to radiant energy in 24 hours by a 40-watt lamp is approximately a kilowatt-hour.

The accuracy with which energy measurements can be made is much less than in the case of the basic quantities of our measurement system. In no case is an accuracy greater than a part in a hundred thousand obtainable, and that accuracy holds for the range from unity to $10^{-6}$ kilowatt-hours. The energy of a ton of coal can be measured to 0.1 percent, but all astronomical energy only to 1 percent. On the other hand, molecular and electronic energy can be measured with reasonable accuracy.

It is expected that a retiring president shall make some mention of the field of science to which he has given special attention. In order that I may not disappoint you I will extend our recreations to include

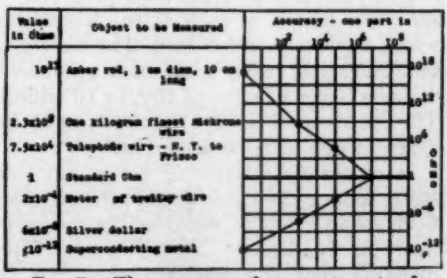
Value in Ohms
Object to be Measured
Accuracy - one part in
Amber rod, 1 cm diam, 10 cm long
One kilogram Planet Matrons wire
Telephone wire - N. Y. to Frisco
Standard Ohm
Meter of trolley wire
Silver dollar
Superconducting metal

FIG. 7.—The accuracy of measurements of electrical resistance.

some of the electrical units. The first of these to be considered is electric potential, which is shown in Fig. 6.

The scale is the same as previously used. The unit ordinate is the volt, which is represented by the electromotive force of a standard cell that can be measured with an accuracy of a part in ten million. The upper limit is the potential of a lightning stroke, and the lower limit is the thermal electromotive force between similar metals.

The second electrical unit to be considered is electrical resistance, represented in Fig. 7.

The unit ordinate is the ohm, which can be measured with an accuracy of 1 part in 10 million, the same as for electrical potential. The values range from $10^{17}$ ohms for the resistance of an amber rod to about $10^{-8}$ for a silver dollar, although a wire of a superconducting metal has a resistance less than $10^{-12}$ ohm, the limit of measurement. An interesting feature of electrical resistance is the possibility of bringing before you objects representing nearly the extremes of the values that are normally measured.

The chart for electrical capacitance is shown in Fig. 8 to illustrate the small extent of some units. The most precise measurements of capacitance can be made on an air capacitor having a capacitance of about 0.1 microfarad. This is equal to the capacitance between two plates, each 4 meters in diameter and 1 mm apart. The capacitance between the earth and the Kennelly-Heaviside layer is only 40,000 microfarads. The capacitance between a ball 2 mm in diameter and the walls of a large room in the center of which the ball is placed is $10^{-7}$ microfarad.

The chart in Fig. 9 has been prepared to show the extent of each of the quantities which have been considered. The scale is a multiplication scale, with each numbered division being a factor of $10^{10}$, or 10 billion. The enormous difference in the extent of the different quantities is apparent.

It would be interesting to extend this study to measurements outside the physical field. As an example, consider the measurement of intelligence. There can be little question that the accuracy that can be attained in determining the I.Q. of an individual in the normal range of intelligence is much greater than for a genius or for a moron. Other examples will doubtless occur to workers in the biological and sociological fields.

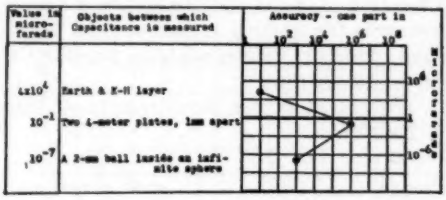
Value in microfarads
Objects between which Capacitance is measured
Accuracy - one part in
Earth & K-H layer
Two 4-meter plates, 1mm apart
A 2-mm ball inside an infinite sphere
Microfarads

FIG. 8.—The accuracy of measurements of electrical capacitance.

The charts that have been given apply only to measurements as they can be made at the present time. Had a scientist of the last generation prepared such charts, the accuracy of measurement would, for almost every quantity, have been appreciably less throughout the entire range. Also, for many of the quantities the extent would have been much less than can now be claimed. It is to be expected that future scientists will improve the accuracy of measurement and extend the range. It is intriguing to contemplate a chart with a series of curves showing, for the beginning of each century for which data are available, the accuracy and extent of the measurement of such fundamental quantities as length, mass, and time. For those to whom this type of recreation has an appeal, there is ample room.

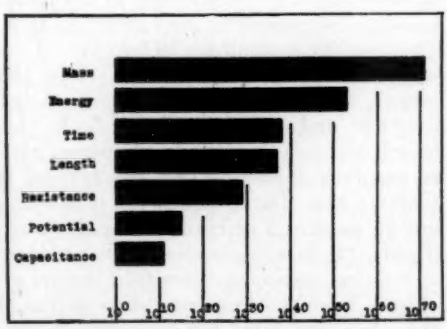


FIG. 9.—The extent of measurements of seven physical quantities.

HISTORY OF SCIENCE.—*The genealogical tree of modern science.*[1] PAUL R. HEYL, National Bureau of Standards.

Science may be defined as an ordered and correlated body of knowledge, as distinguished from a group of uncoordinated facts. Any branch of knowledge which has reached this ordered stage of development may be called a science, though in common usage this term is often understood as referring to what are called the natural sciences—astronomy, physics, chemistry, geology, and biology. There are, however, other branches of knowledge equally entitled to rank as sciences under this definition, such as mathematics, logic, linguistics, economics, ethics, and that which its devotees like to call "the science of sciences"—philosophy. In fact, in the Middle Ages theology was called "the Queen of the Sciences." Viewed from this aspect, the term "science" may be regarded as covering almost the whole range of human thinking; and as it is obviously impossible to cover such an extent of territory in a limited time, we shall confine ourselves to a more restricted field.

The first thing necessary is to get a good perspective of the subject, to see where and when the earliest scientific records are to be found, how scientific centers arose in other places, while the activity of the earlier ones faded away, and to which of these early centers modern science is most indebted for its heritage.

The oldest civilizations are those of China, India, Egypt, and Babylonia. It is not always possible to assign definite dates to the earliest events mentioned in the ancient records of these countries, as these records sometimes disagree among themselves by hundreds of years. All that modern historical scholarship feels safe in saying is that recorded history in China and India dates from somewhere in the third millennium B.C., and in Egypt and Babylonia perhaps a thousand years earlier.

In all these countries (except India) the earliest scientific records are in the field of astronomy. This is but natural, as a practical acquaintance with the rudiments of astronomy is indispensable to primitive people. The sun is their clock; the moon affords a measure of periods of time too long to be counted conveniently in days; and eclipses of the sun and moon must have inspired terror from earliest times.

The astronomy of these early days contained a large element of astrology; nevertheless, a considerable amount of astronomical knowledge was accumulated. In connection with this a parallel development of mathematics was unavoidable. The beginnings of the other sciences came later.

China, for geographical reasons, was long isolated from the western world. Even the silk trade did not become important until near the beginning of the Christian Era, and this involved no cultural relations between China and Europe. The silk was sent from depot to depot, serving the Indian and Persian empires, and changed hands many times along the route. The first Europeans to reach Peking were the Polos, in the latter part of the thirteenth century. Marco Polo records in the account of his travels only one item that may be regarded as of a scientific nature. He says in one place:

"It is a fact that all over the country of Cathay there is a kind of black stones existing in beds in the mountains which they dig out and burn like firewood. If you supply the fire with them at night, and see that they are well kindled, you will find them still alight in the morning; and they make such capital fuel that no other is used throughout the country. It is true that they have plenty of wood also, but they do not burn it, because these stones burn better and cost less."

But Marco Polo's account of the manners and customs of the Chinese was not taken seriously by his contemporaries. He was popularly known as "Marco Millions," and his book was regarded as a collection of travelers' tales. It was centuries before his account of his travels received the attention it deserved.

[1] Address delivered at the 1216th meeting of the Philosophical Society of Washington, March 27, 1943. Received May 15, 1943.

The Chinese annals contain lists of comets dating back ostensibly to about 2300 B.C. The early parts of this record are rather confused, but modern astronomers have checked the later parts and found them intelligible and trustworthy as far back as 611 B.C. The Chinese seem to have been early acquainted with the length of the solar year, as the first Jesuit missionaries, who arrived in China in the seventeenth century, found that it was an immemorial custom among the Chinese to divide a circle into $365\frac{1}{4}°$. The Chinese seem also, at an early period, to have used astronomical instruments with graduated circles by which measurements of right ascension and declination could be made. Some of these instruments, constructed about 1280 A.D., were still to be seen at Peking in 1881. They show that the Chinese anticipated by at least three centuries some of Tycho Brahe's most important inventions, and one of their sages is credited with having measured with considerable accuracy the obliquity of the ecliptic.

The inventions of gunpowder, of printing, and of the magnetic compass are also ascribed to the Chinese. The art of printing from movable blocks was undoubtedly known in China in the early centuries of the Christian Era. It is possible that the claim of antiquity for the invention of gunpowder is also well founded, as explosives were a natural development from the incendiaries used in warfare by all the nations of antiquity. There is some doubt, however, as to the antiquity of the Chinese knowledge of the compass, as their first documentary record of this device is not earlier than the sixteenth century.

But even granting the early invention of all these things, the western world received none of them from China. The beginning of cultural intercourse between Europe and the Far East dates from the arrival of Jesuit missionaries in China in the seventeenth century, and by that time western science had developed to such a degree that China had nothing of value to offer.

The ancient records of India are silent on scientific matters, but it is reasonable to assume that astronomy (or astrology) was not nonexistent there in early times. Indirect evidence of this is found in the growth of Hindu mathematics. About 600 A.D. Hindu algebra and geometry had reached a remarkable stage of development, and to some unknown Hindu sage the western world is indebted for two inventions of the first rank in practical importance—the symbol for zero and the principle of position in numeration. These devices were taken up by the Arabs and later transmitted by them to Europe, whence we speak of the "Arabic" numerals.

In ancient Egypt astronomy was to a certain extent the handmaid of religion. The stars were observed that they might be duly worshiped. These observations, however, were not without their usual practical aspect. For example, the heliacal rising, or first appearance at dawn of the bright star Sirius, heralded the beginning of the rise of the Nile, so important in Egyptian agriculture.

The ancient Egyptian mind excelled in practical engineering rather than in theoretical science. In geometry, the Egyptians laid emphasis on making constructions and determining areas. This was probably a consequence of the necessity of determining boundaries anew after the recession of the annual Nile flood. The Greeks (perhaps rather contemptuously) called the Egyptian geometers "rope-stretchers," rather than philosophers, and there is some evidence that this opinion was not unjustified.

There is in the British Museum an Egyptian papyrus, written by one Ahmes some time before 1700 B.C. It is entitled "Directions for Obtaining the Knowledge of All Dark Things." It shows that the Egyptians of that day cared but little for mathematical theory. It contains practical rules for determining areas, with no theoretical proof. These rules give more or less inaccurate results. For instance, the area of an isosceles triangle whose sides measure 10 ruths and the base 4 ruths is given as 20 square ruths, or half the product of the base by one side. Occasionally, however, the results are rather close. The area of a circle is found by subtracting from the diameter one-ninth of its length and squaring the remainder. This is

equivalent to a value of $\pi$ equaling 3.1604, a very fair approximation.

There is evidence, however, that the ancient Egyptians carried out their engineering work with a high degree of perfection and no little ingenuity. The precise orientation of the Pyramids shows the care with which they observed the heavenly bodies, and in heavy construction they accomplished work which has called forth the admiration of modern engineers.

The quarrying, transporting, and erecting of the many obelisks still standing in Egypt illustrate this engineering skill. It is sometimes said, rather superficially, that the Egyptians had unlimited man power; but a little reflection will show that something more than this was required.

and written records of later periods give us some hints of the methods used.

The Egyptians knew the use of rollers, of the inclined plane, and of the lever. Single pulleys for changing the direction of a rope were used, but pulley blocks and screw jacks were not known. What modern engineer would undertake to move and erect one of these great stones without the aid of these two important mechanical powers?

Two kinds of stone were used by the Egyptians—granite and limestone. The obelisks were cut from quarries in upper Egypt, over 300 miles from the Mediterranean coast, and transported by water down the Nile to the place where they were to be erected. In one of these quarries there was found a broken saw in a cut in the rock.

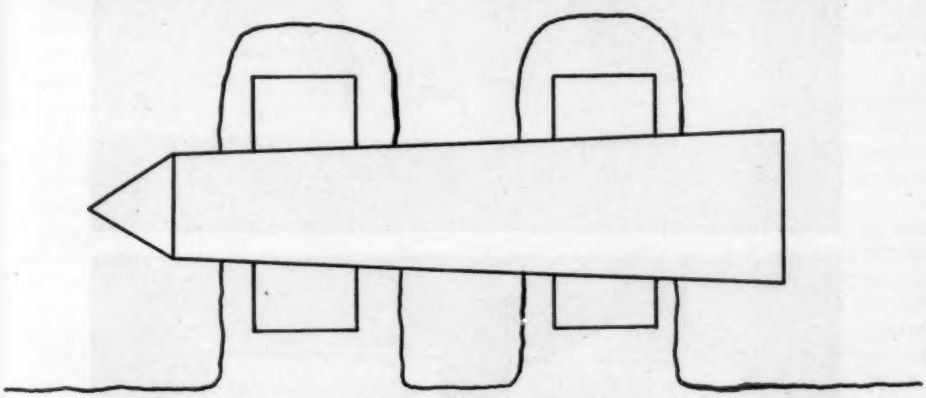

Fig. 1.—Egyptian method of loading an obelisk.

An obelisk 150 feet high, with an average cross section of 100 square feet, will weigh about 1,000 tons. Allowing 2 feet per man, not more than 150 men could stand around one of these great stones as it lay on the ground; and the lifting of such a stone by unaided man power would require each man to lift about 7 tons.

Our knowledge of how the Egyptians accomplished their feats of engineering comes from three sources. The rainless climate of Egypt has preserved for us in their original perfection numerous drawings on the walls of ancient temples and tombs, depicting the daily life of the common people. Remnants of unfinished work are found here and there; This saw was a large two-man saw, of copper or bronze. It had no teeth, but fragments of emery were found lying about it. Mines of emery have been known from remote antiquity in the islands of the eastern Mediterranean. It is obvious that the cutting of the stone was accomplished by feeding the saw with emery and water. It is not an uncommon practice today to cut stone by use of belts of wire rope, driven by a steam engine and fed with sand and water.

The loading of the stone on a boat was a problem requiring considerable ingenuity. A stone weighing 1,000 tons, if it got away from those handling it and fell only 6 inches,

would break the bottom out of any boat. Pliny, in his *Natural history*, tells how this loading was done.

Pliny visited Egypt a thousand years after the obelisk period, but he apparently found a living tradition that he preserved for us; and when I tell you what it was, you will remember it for a thousand years, if you live that long.

The lower surface of the stone was probably not more than a foot or so above the water level. Two large flat boats were then loaded down with stone, pushed under the obelisk —and the stone unloaded!

The obelisk was then floated down the river to the desired locality, and the loading process reversed. Near one of the obelisks at Luxor there is still to be seen the trace of

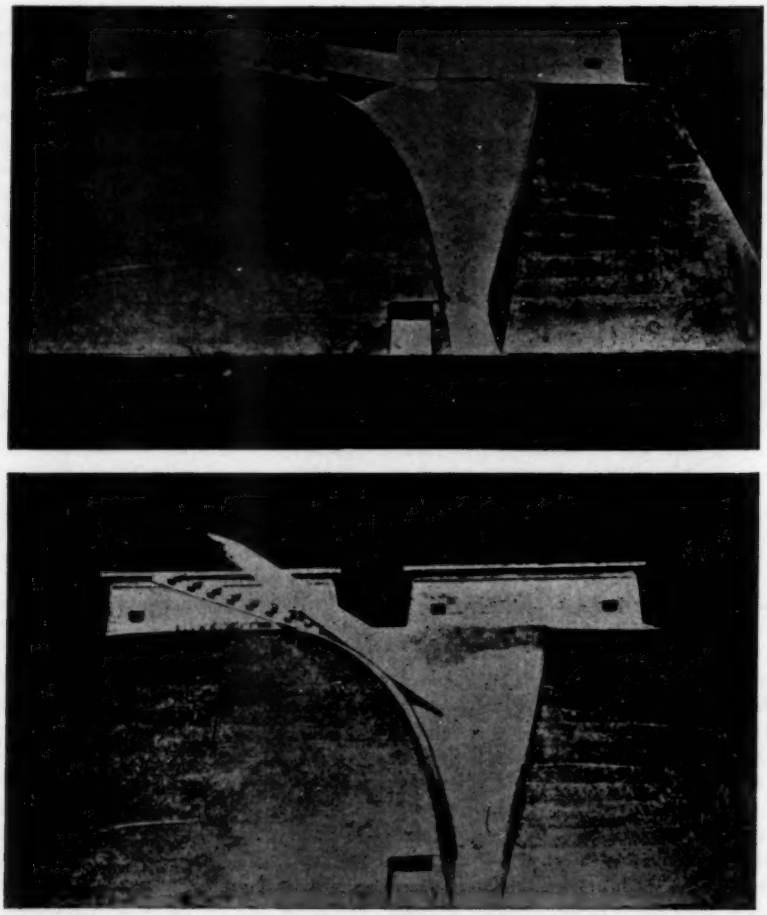

Fig. 2.—Egyptian method of erecting an obelisk.

The method employed is illustrated in Fig. 1. The obelisk was brought down to the river bank and laid parallel to the river. Two canals were dug under it, so that it was supported at the middle and at the ends. the canal by which it was floated in from the river at the time it was erected.

The erection of an obelisk was a task that required still more ingenuity than loading it on a boat. A thousand tons of stone in an

elongated form is not only heavy, but brittle. Unless carefully supported there is danger of its breaking by its own weight. Fig. 2 shows how the erection of an obelisk was carried out.

The first thing was to prepare the stone base. Around this were built up walls of Nile mud, which were tamped down and allowed to dry thoroughly. One of these walls was extended into a long inclined plane. The empty space between the walls was then filled with dry sand from the desert.

The obelisk, supported on a long wooden frame, was then pushed up the incline on rollers, bottom first. On reaching the top its bottom end tilted downward and rested on the sand. An opening was then made at the bottom of the wall and the sand removed, a bucketful at a time. The sand ran down as in a gigantic hourglass, and the obelisk finally came to rest on its base in an upright position.

In chemistry, the Egyptians were probably no farther advanced than other peoples of antiquity. The arts of tanning and dyeing and the production of brass and bronze were widely practiced in ancient times. But by an accident of history the Egyptians contributed something to the science of chemistry that no other nation had an opportunity to do—they gave it its name.

The fertile land of Egypt is a streak of black Nile mud, 5 to 15 miles wide, across the yellow sand of the desert. In the ancient Egyptian tongue the country was called "Khem," or "Khmi," meaning "black earth." When the Mohammedan Arabs came into Egypt in the seventh century A.D., they were interested in the simple chemical arts they found there. They combined an Arabic prefix with the native name of the land, and coined the word "al-Khemi," meaning "the Egyptian art." Not until the middle of the sixteenth century did this word lose its Arabic prefix, and the alchemist become a chemist.

In the early records of Babylonia we find much of importance in the field of astronomy, especially well preserved for us on clay tablets. The principal constellations, as we know them, including the signs of the zodiac, originated in Babylonia. The period called the Saros, of 18 years and 11 days, in which eclipses of the sun and moon repeat themselves very nearly, was discovered in Chaldea at an unknown epoch. By means of this cycle the Babylonian sages were able to predict eclipses. The first "Nautical Almanac" was published annually on clay tablets, now in the British Museum. These tablets contain times of new moon, of heliacal risings and settings, of conjunctions and oppositions of the planets, and predictions of eclipses. One of these old tablets contains an interesting astronomical report:

"To the king, my lord, thy faithful servant, Mar-Istar:

"On the first day, as the new moon's day of the month Thammuz declined, the moon was again visible over the planet Mercury, as I had already predicted to my master, the king. I erred not."

It is from the Babylonians that we have derived our division of the circle into 360°, as they had a calendar of 12 lunar months, which is still preserved by their modern kinsmen, the Mohammedan Arabs.

It was from the Babylonians that the Greeks obtained their first scientific stimulus. The genius of the Greek mind lay not so much in invention as in development and perfection. The great Greek teacher Plato (429–348 B.C.) recognized this when he said: "Whatever we Greeks receive, we improve and perfect." This was well illustrated in the genesis of Greek science.

Greek science did not originate in the mainland of Greece but in the Greek colonies in the Ionian islands in the eastern Mediterranean. It was 200 years before this movement reached the mother country.

About 650 B.C. certain Babylonian sages found their way to the shore of the Mediterranean, where they came in contact with Greek colonists. A school was founded on the island of Cos, which soon became a new center of learning. Among the Ionian philosophers we find the names of many famous scientific pioneers, not only in astronomy and mathematics but also in physics and medicine.

Thales of Miletus was one of the earliest

philosophers of this school. His name is traditionally associated with the prediction of a solar eclipse and with the electrical properties of amber. Pythagoras of Samos was a pupil of Thales, and his name suggests a well-known geometrical theorem. He later migrated to the Greek colonies in Magna Grecia (Sicily and southern Italy), where a new scientific center grew up that later furnished teachers to the mother country.

In the Ionian island of Samothrace, at some time prior to 400 B.C., there was discovered the magnetic toy known as the Samothracian rings. Aristarchus of Samos, about 250 B.C., was the first to suggest a heliocentric theory of the solar system. Hippocrates of Cos, about 450 B.C., is still known as the "Father of Modern Medicine," and framed copies of the Hippocratic oath, which was administered to all candidates for the profession in his day, are now to be seen hanging in physicians' offices.

Certain of these Ionians are known to have visited Egypt, and undoubtedly they profited to some extent by what they learned there, but the greater part of the credit for the origin of Greek science is undoubtedly due to Babylonia.

The rise of Athens and the ensuing Golden Age of Greece (480–338 B.C.) brought in another new center of learning. Here we have the names of Plato and his pupil Aristotle.

With the fall of Athens and the rise of Alexander the Great, a new center of scientific learning grew up at Alexandria. This city was founded by Alexander in 332 B.C., and its first ruler, Ptolemy Soter (not to be confused with the astronomer Ptolemy), offered opportunities to Greek scholars to continue their studies under his auspices. He built for their accommodation the museum where, maintained by royal bounty, they resided, studied, and taught. He laid the foundations of the great Alexandrian library and originated the search for copies of all written works, which resulted in the formation of a collection such as the world has seldom seen. The successors of Ptolemy Soter carried on his original plan vigorously, and one of them, Euergetes (247–222 B.C.), compelled all travelers who arrived in Alexandria to leave a copy of any literary work that they possessed.

The Alexandrian school, though located on Egyptian soil, was essentially Greek in its personnel and habits of thought. About 80 B.C. Egypt came under Roman domination. After this time the character of the school gradually suffered a change. The earlier scholars had devoted themselves to science and literature, while in later times their main interest was in what we would now called philosophy. Yet while it lasted (until the fifth century A.D.) the school of Alexandria included some great names: Euclid (about 300 B.C.); Apollonius of Perga (200 B.C.), the author of a treatise on conic sections; Eratosthenes (230 B.C.), who made the first measurement of the circumference of the earth; and Hipparchus (160–125 B.C.), who found the epicyclical theory of the heavens, later known as the Ptolemaic system, from its most famous expositor, Claudius Ptolemaeus.

The culture of Rome was largely borrowed from the Greeks. The Romans excelled in their own right in law and administration and developed considerable ability in the building of roads and aqueducts, but manual labor of any kind was held to be degrading. Seneca (3 B.C.–65 A.D.) said:

> In my own time there have been inventions of this sort, transparent windows, tubes for diffusing warmth equally through all parts of a building, short-hand which has been carried to such a perfection that a writer can keep pace with the most rapid speaker. But the inventing of such things is drudgery for the lowest slaves; philosophy lies deeper. It is not her office to teach men how to use their hands. The object of her lessons is to form the soul. In them there is nothing of instruments for the necessary use of artisans.

With such a stigma resting upon it, no great development of science could have been expected under Roman auspices. The fall of Rome (476 A.D.) made matters worse, for the barbarians who overwhelmed Rome had no traditions of culture; and in addition to this indifference to science there developed in Europe a positive hostility to it in an unexpected quarter.

In the early centuries of the Christian Era there existed a widespread belief that the Last Judgment was close at hand and might be expected to occur within any one's lifetime. In consequence, time was precious and should be devoted to saving souls rather than to the study of natural phenomena that were so soon to pass away. Eusebius, bishop of Caesarea in Palestine (260–340 A.D.), speaking of scientific investigators, said: "It is not through ignorance of the things admired by them, but through contempt of their useless labor that we think little of these matters, turning our souls to better things." His successor, Basil, declared: "It is a matter of no interest to us whether the earth is a sphere or a cylinder or a disk, or concave in the center like a fan."

As the years passed and the last day did not occur, the prophets revised their calculations and finally announced that the great event would happen in the year 1000. This prediction received wide belief and was a factor in prolonging for centuries in Europe the idea that the study of nature was a waste of time. When the year 1000 finally arrived this belief was as strong as ever. Many European peasants thought it useless to till their fields, and in consequence much suffering occurred.

This feeling that scientific study was a waste of precious time undoubtedly had much to do with the almost total eclipse of science in Europe during the Middle Ages. However, during this period scientific knowledge was kept alive in the East by the Arabs.

Arabia, at the time when Mohammed came upon the scene (about 613 A.D.), was in a state of political chaos. Part of it was under Persian influence; the rest of the population either lived in towns, each of which had its own government, or else belonged to various wandering tribes maintaining the traditions of family and tribal rule and fighting continual battles with one another. Mohammed's success in welding together this apparently unpromising material into a united and conquering nation is one of the wonders of history. At his death in 632 he left Arabia practically unified. His successors conquered the whole of northern Africa and crossed the strait of Gibraltar into Spain, where they remained an important element of the population until the time of Columbus. The post-Mohammedan Arabs encouraged learning, exalted the supremacy of reasoning, founded schools from Bagdad to Granada, and did everything possible to apply scientific knowledge to the purposes of every day life, so much so that the Crusaders were astonished at the magnificence and splendor of the civilization with which they were confronted. Arabic scholars made translations from the Greek writers and added contributions of their own. The extent of the scientific knowledge of the Arabs is illustrated by the following words, all of Arabic origin, which still preserve their original signification—nadir, zenith, alchemy, alkali, algebra, cipher, carat, elixir. The esteem in which the Arabs held scientific study at a time when Europe regarded it as worthless is illustrated by a burst of enthusiasm from one of their own writers (850 A.D.), who said: "In the Last Day, may Allah have mercy on the soul of Al-Razi, for he was the first of mankind to draw up a table of specific gravities."

It is impossible to regard this change in the group psychology of the Arabs in post-Mohammedan times without feeling that there must have been something dormant in their heredity that responded in its own way to the general stimulus given by Mohammed. It is unthinkable that Mohammed could have brought about the same result with any of the tribes of central Africa. In this connection we think at once of the intellectual achievements of that other ancient branch of the Semitic race—the Babylonians. Scientific learning seems to have been indigenous to the soil of ancient Arabia.

It is true that there is another side to this story. Besides those Arabs who kept the lamp of learning burning, there were others, religious fanatics, such as the Caliph Omar, who ordered the destruction of the remnants of the great Alexandrian library on the ground that if the books agreed with the Koran they were useless, and if they did not they were pernicious, and should be de-

stroyed. Fortunately, Arabs of his type seem to have been an insignificant minority.

To return to Europe, after the critical year 1000 had passed the people seem to have gradually lost faith in the prophets of doom, and interest in scientific investigation began to reappear here and there. In the latter part of the twelfth century the magnetic compass came into use, and in the thirteenth century we have Roger Bacon, a scientific pioneer.

The revival of interest in science in Europe was a part of the general renewal of interest in learning. The Renaissance period was not, as it is sometimes represented, a sudden break with medievalism and a birth of the modern world. It extended over a period of a century or more. A number of conditions favorable to the rapid development of learning happened to coincide, and as a result man's outlook on himself and nature in general became profoundly modified.

One of these conditions resulted from the capture of Constantinople by the Turks in 1453. With the fall of the Byzantine Empire many learned Greeks fled into Italy, bringing with them manuscripts of Greek literature and (what was more important) the ability to read them. A revival of interest in the culture of the ancients ensued, especially in Italy, which became the chief center of the Renaissance.

The invention of printing at about this time made it possible to obtain many copies of books at a comparatively trifling cost, and the voyages of Columbus produced new ideas and prepared men's minds to accept the more human and naturalistic view of the universe which had been current among the Greeks, in place of the mystical aspect which it wore to the medieval schoolmen and ecclesiastics.

It will be seen from this brief sketch of the genealogical tree of European science that its roots are to be found in the ancient civilizations of Babylonia, Egypt, and India, in the order of importance as named. It is probably safe to say that Babylonia contributed more than Egypt and India together. The contributions of these ancient civilizations converged, partly for geographical reasons, on Greece, where they fell on fertile soil. From the Greeks this heritage of knowledge passed to the Romans, and later, on the decline of Greece and Rome, it passed to the Arabs, who were its custodians until the revival of learning in Europe.

## ETHNOLOGY.—*Hokan discovered in South America.*[1] JOHN P. HARRINGTON. (Communicated by WILLIAM N. FENTON.)

The purpose of this paper is to show the Hokan affinity of Quechua, "lengua general," that is, general language, of the Inca Empire, formerly, and still at the present day, spoken in large parts of what are now the countries of Peru, Ecuador, and Bolivia, in South America, and much heard at the present moment even on the streets of Cuzco, Quito, and Potosí. Hitherto the affinity of Hokan has been carried only to the Subtiaba language of the Pacific watershed of Central America.[2] The present discovery carries Hokan a step farther, and for the first time unites the two continents of North and South America linguistically. I wish to express deep indebtedness and gratitude to Dr. Luis E. Valcárcel and to Prof. J. M. B. Farfán, the latter having gone farther than any other person in a bold analysis of Quechua linguistic forms.

Following Sapir's discernment that similarity of meaning should have precedence over similarity of sound as a guide in the assembling of forms for comparison, Farfán and the present writer, with entirely different backgrounds, have analyzed Quechua forms, with the result of becoming entirely convinced that these are made up of agglutinated elements, stereotyped and worn into a peculiarly nonperspicuous condition. Bases and their endings, and even bibases in origin, have become phonetically improved and evaluated for statement and for labeling of entity. But in origin Quechua forms

[1] Received August 28, 1943.

[2] SAPIR, E., *The Hokan affinity of Subtiaba in Nicaragua.* Amer. Anthrop. 27: 402–435, 491–527. 1925.

were conglomerations, like those of other Hokan languages, consisting of bases and affixes amalgamated together, and are still thus composed, and could be advantageously pried apart, if we only had some good means of doing so with certainty. Quechua doubtless contains bases of first and of second position and many affixes. The Quechua language has changed through countless generations since the time when it was more nearly related to Hokan, many of those which were perhaps in early times principal forms having gone out of use. Yet the main Hokan traits of affinity still remain, in sounds, in structure, in vocabulary. The assumption of the present status has been attended with ablautings of vowels and with changings of consonants. Component sounds in various settings have developed differently; yet in spite of this phonetic shifts can be worked out, some of them not too good, and being not too good they are the more convincing for showing genetic affinity. Hokanity pervades the entire make-up of Quechua.

We simply do not possess a good approach to the analysis of Quechua. The dialects of Quechua are not sufficiently differentiated for furnishing such an approach. And there is no extraneous language closely enough related to Quechua to render synchronic findings in it well worth while. Early recordings in Quechua itself throw light on only a few forms.

*The name of the Quechua language.*—The native name of the Quechua language in Quechua itself is runasimi, which means literally a person's mouth, but the second member is extended by metaphor to signify language, so that the whole means native's language, coinciding exactly with the current Spanish term: lengua general. The language is called Quechua in Spanish, but not so in Quechua speech itself. The geographical term qheswa, mountain valley, was also used as a place name and from this usage became applied to an inhabitant or collectivity of inhabitants of a place. The term qheswa was in use meaning inhabitant of the province of Cuzco, and from this use it was only a step to the taking of the term into Spanish in the form Quechua and as the name of the language in its entirety.

*Loan words of Quechua origin in Spanish.*—No better appreciation of the prominent position of the Quechua language with regard to influence on Spanish can be gained than from an examination of some of the words common in Spanish which have come into it from Quechua. A large bilingual population has for generations helped along this borrowing. Well-known Spanish words which have found their way into Spanish from Quechua are: Andes (from anti, mountain-region); campa, Campa (from kampa, coward); chaco, Chaco (from tcaku, hunt); chacra (from tcaxra, cultivated field); charqui (from tcarki, jerky); cóndor (from kuntur, condor); Cuzco (from Qotcqo, name of the Inca capital); guacamayo (from wakamayu, macaw); guano (from wanu, manure); pampa (from pampa, plain); papa (from papa, potato); pita (from pita, string); puma (from puma, mountain lion); puna (from puna, elevated plain); quina (said to be from kina, Peruvian bark); quipo (from qhipu, knot).

*The three approaches to the analysis of Quechua.*—(1) The main approach will always have to be internal analysis within the Quechua language itself, by comparison of forms with related ones and with forms not related. It was by internal analysis and with a guiding background knowledge of some of the Hokan languages of North America that realization of the Hokan nature of Quechua first dawned upon me. Starting with wi-qe, tear, which reminded me vividly of Pomo yu-xa, tear, lit. eye-water, i.e., eye's moisture, I obtained old Quechua elements for eye and for water: wi-, eye; -qe, water. It was easy to see that Quechua nyawi, eye, also occurring in nyawpa, in front of, must have replaced an older and once dominant wi-, eye. Three forms are to be found of the old word for water: -qe, as in wi-qe, tear; qo-, for instance in qo-tca, lake; and qa, seasonal stream. Sun-kha, beard, was sensed to be literally mouth-hair, the first syllable a form of simi, mouth, the second syllable evidently to be identified with qa-, skin, pelt. To adduce the very rare great similarity between Quechua and a Hokan language far north, I formed wa-si-lya-y, my little house, and compared it with Chimariko a-wa-lla-'i, my little house.

Comparison within Quechua itself sometimes shows what is the meaningful part of a word. For instance, it becomes apparent that haly- signifies earth, upon comparison of (h)aly-p(')a, earth; haly-pi, to dig; haly-ma, to dirty. Sometimes one is at a loss to know which forms to select for comparison. Thus pa-na, sister, and pa-ya, old woman, may belong together.

2. It is rare indeed that early spellings of Quechua are helpfully divirgent from the present-day ones. Examples of useful early spellings are rinkri, ear, now oridinarily rinri; -kta, objective, not standardly -ta.

3. Sometimes a dialect of Quechua, divergent in its retention of a form, offers material for comparison which the standard language does not offer. Thus phy-yu, cloud, is shown by the Cajamarca dialect of Quechua pu-kuta, cloud, to have its first syllable carry the meaning of cloud. Notably the Chinchay dialect of Quechua, a vocabulary of which first was published in the second edition of Torres Rubio's *Arte de la langua Quechua*, Lima, 1700, is removed from the standard Quechua as regards forms and vocabulary.

Comparison of Quechua with the Hokan languages is more restricted by lack of sure analysis in Quechua than by any other factor.

*Metaphorical extension of definition.*—When for instance nyaw-sa, blind, lit. not having eyes, is found to have had its meaning extended by metaphor to sightless, we contemplate what has been called a metaphorical extension of meaning. Metaphorical means, literally, carrying beyond.

*Ranking of elements negligible as regards comparison.*—It is found again and again upon comparing extraneous Hokan forms with Quechua that the compared elements override the weight which they have assumed in a given language, with the result that a theme or base has sometimes to be compared with an affix, or vice versa.

*Abbreviations.*—The name of the language from which taken is placed before a compared form. If the name of the language is short, or if the name occurs rarely, it is written out in full. And in general description, language names are not abbreviated. For instance, Yana, the name of a Hokan language of California, is so short that it would be unnecessary to abbreviate it. The few language names which it is advantageous to shorten as labels of provenience preceding cited forms are:

| | |
|---|---|
| Chim | Chimariko |
| Choct | Choctaw |
| Q | Quechua |
| Sal | Salinan |
| Subt | Subtiaba |

## Phonetics

In bird's-eye view, the Hokan languages show a contrastive distinguishing of six vowels, for the most part, which vowels can be written by the familiar symbols: a o u e i ə. Some of the Hokan languages furthermore distinguish short and long vowels, but Quechua does not.

In far perspective as regards consonants, what may be called the principal characteristic of the Hokan languages is that while many of them, as for instance Yana, have only one articulatory series produced by the back of the tongue and again only one produced by the front of the tongue, Quechua, for instance, has two back-of-the-tongue series, which could be spoken of as the q and the k series, and Salinan is noted for possessing two front-of-the-tongue series, which could be spoken of as the ţ and the t series. No Hokan language has been found which has both the two rear and the two front series.

It is a general feature of the phonetics of the Hokan languages to have developed, in addition to unaspirated clusives, which would naturally be written with the unaspirated values of Spanish t and p for instance, also a clicked variety of clusives, and again a strongly aspirated variety of clusives, thereby greatly increasing the number of distinctive consonant sounds.

The Hokan system of consonants, without listing in separate lines the doubling of rear or of front series, yet taking into cognizance the widespread triple appearance of clusives as unaspirated, clicked and aspirated, would be somewhat as follows:

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ' | h | | | | | | | | | | | |
| k | k' | kh | x | | | | | | | | | |
| y | | | | | | | | | | | | |
| t | t' | th | c | tc | tc' | tch | s | ts | ts' | tsh | r | n |
| p | p' | ph | w | m | | | | | | | | |

*Comparison of sounds.*—Widespread studies have shown that consonant sounds when syllabo-initial and again when syllabofinal diverge in development, and that languages long apart, as for instance Quechua and Yana, have been preceded by scores of generations of linguistic change of which there is no record, of which change we do well to puzzle out the results without ever being able to learn the details of development. Both vowel and consonant appearances in Quechua are shockingly diverse. Rit'i, snow, appears in the Ancachs dialect of Quechua as raku, snow. Even articulatory series of consonants are not adhered to in development. Thus urqo, mountain; hirka, mountain top. Appearance of a word with two of the three forms of clusive can be illustrated by: qoso, husband; qhari, man in prime; Cajamarca Q tayka, heel; Q t'ayku, heel.

VOWELS:

*a, o, u—a*

Q qaqa, rock; Pomo kabe, stone; Sal (t)cxa', stone; Q -qo, water; Yana xana, water; Pomo -xa, water; Q phuyu, cloud; Sal pa·'i'', cloud.

*u, a—o*

Q pu-, to sleep; Chim po-, to sleep; Subt -apo, to sleep; Q mukiy, to be suffocated; Sal (i)mo'kLop, to be drowned (pl.); Q muqo, knee; Pomo mōko, knee; Q matcay, cave; Pomo mo, cave. It should be noticed in this connection that Spanish o regularly appears as u in Spanish loan words into Quechua. Thus Spanish cotón, shirt; Q kutun, shirt.

*u, w—u*

Q phu-, to blow; Pomo pu-, to blow; Q wi-, eye; Q uy-a, face; Pomo ui, eye.

*a, i—e*

Q amu, mute; Yana 'ému, to stop crying; Chinchay Q tcatca, old woman; Sal tc'ene'', old woman; Q waman, falcon; Chim wemer, eagle; Q silyu, unguis; Sal icele'', unguis.

*i, u—i*

Q silya, gravel; Subt si·nu, stone; Q nyiy, niy, to say; Pomo ni, to say; Q tuta, night; Chim diwe-, night.

CONSONANTS:

*', q, y—'*

Q iwa, plant, tree; Subt i·ci, tree; Q qalyu, for *'alyu, tongue; Chim -pen, tongue; Q yawar, blood; Sal a·'kat, blood.

*h—h*

h is non-occurrent in any of the Hokan languages except in interjection or song padder, or as a secondary development.

*q, qh, k, w—q, k*

Q khipuy, to tie; Pomo qo, to tie; Q qowi, cuy; Sal kol', hare; Q orqo, male; Q qosa, husband; Q qhari, man in prime; Pomo kawi, boy; Q kun-ka, neck, throat, voice; Chim -ki, neck; Q yawar, blood; Sal a·'kat, blood.

*k—k'*

Q kuru, worm; Sal ck'ot, snake, worm, grub.

*q', qh—x*

Q saq'aqa, bone of dead; Sal axa'k, bone; Q qho-, nose; Chim -xu, nose.

*t, r, n—t, d, n*

Q tayta, father; Sal te·le'', father; Q inti, sun; Pomo da, sun; Sal na, sun. Within Quechua itself one finds Q pirutu, piruru, bone-flute; Q tchataku, ragamuffin, tchanaku, rag.

*t, tc—tx*

Q tulyu, bone; Chim -txun, bone; Q tawna, walking-stick; Sal itxau, cane; Q tca(n)ka, leg; Chim -txan, leg.

*tc'—tc*

Q tc'ini, small; Chim tcitc, child.

*tc—tcx*

Q tcuta, to drag; Chim-tcxa-, to pull.

*s, r—s*

Q sonqo, heart; Chim -santce, heart; Q simi, mouth; Pomo si-, with the mouth; Q rin(k)ri, for *sinkri, ear; Shasta isak, ear; Q yawar, blood; Chantal awas, blood.

*tc—ts*

Q tciwtci, fledgeling; Pomo taita, bird.

*ly, y—l, n*

Q qalyu, tongue; Chim -pen, tongue; Sal epa·'l, tongue; Q ilyay, to shine; Yana -'lai-, to warm; Sal lo·L, to get burnt; Q muyu, circle; Chim nolle, round; Q nyoqa, noqa, I; Chim nōut, I.

*y—y*

Q ay-a, corpse; Yana ya, person; Q yu-, to think; Pomo -yi-, referring to thinking.

*p—p, b*

Q ispiwi, lamp; Chim pi'a, n, fat; Q para, rain; Yana ba-ri-, to rain; Q pupu, navel; Chim -napu, navel.

*w—w*

Q wira, n, fat; Pomo wi-m, n, fat; Q wanu, manure; Chim -wax, excrement; Sal p'xat', excrement, intestines; Q wixsa, belly; Pomo wōxa, belly.

*p—m, b*

Q patca, the earth; Pomo ma, earth; Chinchay Q paqa, head, chief; Chim me-, with the head; Pomo ba-, with the head.

*Accent.*—Each Hokan language has its own accentuation. In Quechua the accent has settled on the penult, but is kept distinctive on the ultima in words in -tcá, dubitative. The Chinchay dialect of Quechua has inherited more of the ultima accentuation than has the standard Quechua.

## Morphology

Morphology, as the term is applied to language, is the study of denotatory form, Greek morphêe being the equivalent of Latin forma, both signifying form. Morphology amounts in actuality to the analysis of words, the word consisting of a denotatory theme, or of extended theme known as base, or of a pair of these, without or with affix or affixes. A general term for the denotatory element of language is morphom. Identity of usages and parallelism of the words for ant and fear convince me with Brugmann that foorma and morphée are the same word, while Sanskrit shows that it is the Greek which has become metathetical, the Latin and Greek originating background having been *thormáa.

The Hokan languages have two parts of speech: actional and substantival. The actional is split into four etymal classes: verb, adverb, conjunction, and interjection; the substantival is split into three etymal classes: noun, adjective, and pronoun. The actional is the main part of speech, the substantival being subsidiary, or adverbial, to it.

Almost every linguistic form is what could be termed in Latin: versiformis, changing in form.

A widespread Hokan trait is the infrequent occurrence of a completely duplicated word, which could bear such Latin terminology as reduplicatio tanta. Such duplication occurs in Quechua, where there is a tendency in the vernacular writing of the language to place a hyphen between the two duplicate members: sira-sira, scorpion.

A thorough study of compounding in several of the Hokan languages, including Quechua, has arrived at the conclusion that all compounds are double only, consisting of an antebase and a postbase, each of which may not, or may, in itself be a compound, the two together constituting a bibase. Furthermore, in all these languages it is illuminating that the modificatory precedes the modified, the postbase constituting the main weight of the compound and carrying the conjugation or declension, or whatever is the inflection of the bibase as regards sentence. When the postbase is a verb and the antebase is a noun or adjective, the noun or adjective is adverbial to the verb. Although vernacular orthography may employ the custom of writing antebase and postbase as separate words, or of writing affix as a separate word, as is largely in vogue in the vernacular writing of Quechua, cobasing and affixing are the actual status and writing as a single word is preferable; an affix is never etymable and in this an affix differs from the usual theme or base. Every compound in Quechua is a doublet. Thus the well known Quechua compound inkawasi, palace, lit. emperor-house, is a bibase, each of its members consisting of a theme enlarged by addition of a little-understood postfix, but if either, or both, of the members were in itself a compound, the entirety would still be a bibase, and this is a characteristic not only of Quechua, but of every Hokan language that I have looked into. Postbasal or the like is often a shortcut term for postbasal noun, to which term postbasal adjective is to be contrasted.

Languages far apart sometimes co-inherit minor traits. One should notice a widespread peculiar feature of Hokan compounding which consists of an -n- of un-

known origin thrust between the two bases of certain bibases, while other bibases do not have or permit of this. Thus Q uma-ntulyu, skull, lit. head-bone; but Q uma-qara, scalp, lit. head-skin; Chim hīmi-n-alla, moon, lit. night-sun; Chim hīmi-samdu, devil

In Quechua very rarely a postbase is on the verge of becoming a versal postfix. Thus -ruma, person, which frequently occurrs merely with the force of a gentiliceous postfix. Or the meaning of one of the bases of a bibase may have become obscure, as in Q kaw-lyama, llama divinity, the first base of which has lost assertion of a meaning which it must once have had.

Again, where one might expect to find cobasing in Quechua, the antebase may be represented by the postpositioned form of a noun or adjective. Thus Q wasi-q punku, house door, lit. house's door, instead of wasipunku, house door.

It is a widespread trait of the Hokan languages, including Quechua, to vary the form of certain much-used postfixes with the result of producing a better fitting together. Doublet forms arise, one postvocalic, and the other postconsonantal. The shortest way of indicating such two forms is to let v stand for vowel, c for consonant. Thus in Subtiaba a certain postfix has the doublet forms: v-yū, c-ū. If a postfix does not have doublet forms, even a harsh coming together of consonants has to occur. Thus Q takeq-kuna, singers. Whenever a morphon manifests itself in two forms, these forms are known as doublets, and each has a separate background and usage; just as pre-Latin *dvis- appears both as dis- and bis-.

Another feature common to many Hokan languages and shared by Quechua is that now and then a base without change functions in two or more etymal classes. Thus Q tcalywa, to fish, fish. Or the functioning may be in two etymal subclasses. Thus Q nyawpa, locational adv., in front of, temporal adv., long ago. In Quechua in rare instances a noun can even occur as a postposition.

*Hyphenization to indicate analysis.*—Navarro Tomás has a system which employs seven different "signos analíticos" for indication of pried apart constituent elements of a word. Common usage employs instead of this system, advantageous when one gets used to it, merely the hyphen for indication of such analysis.

*Listing of affixes.*—The Hokan languages on the whole run largely to the postfixation of affixes. Yana for instance has no prefixes at all, and Quechua recognizes only eight. It is practical to list affixes separately according to whether prefixed or postfixed, under each of the speech classes to which the affix can be added, and in three lists as regards whether the affix is sentential, versal, or paradigmatical.

## ACTIONAL

The main part of speech is the actional, presented before the other part of speech, which is the substantival, because this presentation conforms with psychology. Dinner should be presented before dessert, verb before extraneity, all of which is merely expletive to the verb.

## VERB

The Quechua verb is thoroughly Hokan in its complications, having only one mode (I include the imperative, hortatory, and prohibitive in this mode), no gender, singular and duoplural number, progressive, integral and static aspect, four tenses, including near and remote past, and a passive voice built by coupling the static participle with the verb to be. An example of this last formation is Q rikusqa kany, I am seen, formed from Q riku-sqa, seen.

### *Verb Affixes*

#### *Verb Sentential*

Q -taq, interrogative; Pomo da, interrogative.

#### *Verb Versal*

##### *Prefix*

Q as-, slightly (compare Q as, numeric pronoun, a little); Sal as, child, son; Subt ax, a little.

##### *Postfixes*

Q -ku, reflexive; Yana -gu-, self.

Q -lya, petitive; Chim -la, diminutive.

Q -pu, applicative; Yana -t'p'au, own.

Q -ri, future; Yana nĭ, ni, to go; Pomo ne-, to go.

Q -tcá, dubitative; Chim -dialhin, dubitative.

Q -tci, causative; Yana -dju, causative; Choct -tci, causative.

*Verb Paradigmatical*

Q -i, imperative; Yana -'i', imperative with third person object; Subt -la, -l, imperative.

Q -n, present; Chim -n, -ni, -in, incompleted action, present; Pomo -n, present.

Q -na, future static participle, purposive, instrumentative; Sal na-, purposive; Choct na, instrumentative.

Q -q, -qe, present participle; Pomo -k, agentive.

Q -sqa, static participle; Chim -ak, completed action; Sal -k, static participle.

Q -y, infinitive; Yana -'i, infinitive; Sal i,-versusverbal nominal.

*List of Verbs*

Q hanlyay, to yawn; Chim -xaca-, to yawn.

Q hap'iy, to take; Choct habe-na, to receive.

Q kaniy, to bite; Q kiru, tooth; Yana -gal, to bite; Pomo g'a-, with the teeth.

Q kay, to be; Pomo ke-m, to be.

Q kirpay, to cover; Choct ialipa, to cover.

Q kutcuy, to cut; Choct katce-li, to cut.

Q mi-, to eat; Chim ma, ama, to eat; Sal ama, to eat.

Q mukiy, to be suffocated; Sal *(i)mo'kLop, to drown (plural).

Q munay, to love, to want; Chim mi'ina, to like, to love; Pomo mara, to like.

Q nyiy, niy, to say; Pomo ni, to say.

Q onqoy, to get sick; Q umphu, sickly; Q unay, to delay; Subt -ndi·yu, to be sick.

Q pakiy, to break tr; Sal (k)a'p'axtenop, to smash, to shatter.

Hunancayo Q paly-puy, to fall; Yana mɪdja-, to be heavy; Choct il-beca, heavy.

Q pampa-tcay, to even, to forgive; Yana -p'al-, to be flat; Pomo pai, a flat.

Q punyuy, to sleep; Chim po-, to sleep; Subt -apo, to sleep.

Q puttutuy, to stink; Chim -potpot, to boil; Sal (k)o'poṭoṭ'na, to boil.

Q -puy, to swim; Yana p'u-, to swim.

Q phatay, to burst tr.; Choct mita-i, to burst intr.

Q -phay, to wash, in u-phay, to wash the face; Chim -pok-, to wash.

Q phukuy, to blow; Yana p'ô-, to blow; Pomo pu-cul-, to blow.

Q -qoy, to sleep; Subt -gu·, to sleep.

Q raqray, to split intr.; Q raxra, a crack; Pomo dak, to split.

Q rikuy, to see; Yana da-, to see.

Q riy, to go; Yana nɪ, ni, to go; Pomo ne-, to go.

Q ru-, to burn intr.; Q nina, fire; Choct lua, burnt.

Q ruray, to do, to make; Sal ti', to do; Subt -da, to make.

Q saqtay, to pound up; saq-ma, a blow with the fist; Pomo sax, to strike; Choct isso, to strike.

Q takiy, to sing; Chim tak-, to sing.

Q tiyay, to sit, to stay; Q tuhu (archaic), chair; Subt -ta·u, to sit.

Q t'aq-lya, a slap; Yana -t!at'a-, to pat, to slap; Pomo t'ap, to slap.

Q t'i-piy, to pull up by the roots, to pull out (a hair); Choct ti$^{a}$fi, to pull out or up.

Q tcuray, to put; Q tcurkuy, to load; Choct tala-li, to put.

Q tc'aqtcy, to water; Q tc'aran, moist; Q tcapuy, to dip; Choct tcəbbi, to dip.

Q urmay, to fall; Q ura, beneath; Q urupi, below; Yana -di-, -dɪ-, down.

Q wanyuy, to die; Subt -nyu-, to die.

Q waqay, to cry; Chim wõ-, to cry; Yana -wa-, -wā-, to cry; Sal xāta, to cry.

Q yuypay, to count; Pomo mi-yi, to count.

## ADVERB

### *Statemental Adverb*

#### *Negative*

Q manan, no, not; Chim -nan, negative.

Q -tcu, negative; Chim xu-, not; Yana k'u-, not; Pomo kui, not; Sal ko-, not.

## SUBSTANTIVAL

## NOUN

### *Noun Affixes*

#### *Noun Versal*

##### *Postfixes*

Q -tca, nominal, diminutive nominal; Yana -tsli, collective diminutive nominal.

Q -na, nominal; Yana -na, -la, nominal.

Q -r, nominal; Chim -r, nominal.

Q -lya, nominal, diminutive nominal; Chim -la, diminutive nominal.

#### *Noun Paradigmatical*

##### *Postfixes*

Q -kuna, duoplural; Chim -kule, duoplural, in qā'-kule, ye.

Q -wan, instrumental, comitative; Chim -mdi, -mdu, instrumental; Choct -iba, instrumental.

### *List of Nouns*

#### Plant

##### Plant Parts

Q i-wa, plant, tree; Choct iti, tree; Subt i·ci, tree.

Q maly-ki, tree; Q mily-m(w)a, wool; Q maly-qo, fledgling already having fuzz; Q maly-ta, whelp, young mammal; Choct bafəlli, brushy.

Q qisqa, thorn; Q khisa, nettle; Q khisa-kuru, fuzzy caterpillar; Sal xa'ke, spine.

#### Animal

##### Animal Parts

###### *Corporeal*

Q ay-a, corpse; Q ay-lya, meat; Q ay-tca, meat; Q ay-lyu, kinsperson; Yana ya, person.

Q han-k'u, sinew; Q han-k'a-tcakiy, to limp; Yana ba·ma, sinew.

Q yawar, blood; Chinchay Q yaar, blood; Q yawi-ru, soldier; Chontal awas, blood.

Q wi-ra, n, fat, lava; Q wira-p'uku, lantern; Q wira-qotca, god, God, Mr., lit. lava-lake; Pomo wi-m, n, fat.

Q saq'aqa, bone of dead; Sal axa'k, bone.

Q tulyu, bone; Chim -txun, bone.

Q tcuxtca, bodyhair; Sal ecax, feathers, whiskers.

Q qa-ra, skin, pelt; Q sun-kha, beard; Pomo he-le, hair.

Q aka, excrement; Q aka-yoq kelyay, rusty iron, lit. iron having excrement; Q t-axya, ball-excrement (e.g. of llama); Chim -wax, excrement; Yana wak'i-, to defecate.

###### *Head*

Chinchay Q pe-qa, head, chief; Chim me-, with the head; Pomo ba-, with the head.

Q yu-yay, to think; Q yu-kay, to deceive; Q yu-pay, to count; Q yu-yay-kuy, to imagine; Q yu-yay-sapa, discreet; Pomo ba-yi, to teach; Pomo mi-yi, to count.

Q ma-t'i, forehead; Chim -mo-sni, forehead.

Q rin(k)-ri, for *sink-ri, ear; Shasta isak, ear; Atsugewi asmak, ear.

Q wi-, eye, in wi-qe, lacrima; Q uy-a, face; Shasta oy, eye; Pomo ui, eye; Sal u·, face.

Q wi-qe, lacrima, lit. eye-water; Pomo yu-xa, lacrima.

Q qho-nya, nose mucus; Q qho-rqoy, to snore; Chim -xu, nose.

Q simi, mouth; Q sin-si, to show the teeth; Q sun-kha, beard, lit. mouth hair; Q san-qa, roof of the mouth (with -qa compare wasi-qata, house roof); Pomo si-, with the mouth.

Q qalyu, for *alyu, tongue (from qalyu has come into Spanish Callao, name of the principal port of Peru); Chim -pen, tongue; Sal epa·'l, tongue.

Q kiru, tooth; Q ki-pi, worn-down dentition; Q kaniy, to bite; Yana -gal, to bite.

Q kun-ka, neck, throat, voice; Q kunay, advice; Chim -ki, neck.

Q wax-ra, horn; Chim -wec, horn; Yana weyu, horn.

###### *External Trunk*

Q qhasqo, chest; Chim usi, chest; Sal ico", chest.

Q tcutcu, female breast; Chim ci-ra, female breast; Yana tc'ik'i, female breast.

Q wixsa, belly; Pomo wōxa, belly.

Q pupu, navel; Chim -napu, navel; Sal xapi'-cucwe·t, navel.

Q wasa, dorsum; Subt giitca, behind.

###### *Viscera*

Q sonqo, heart (also used with congruent noun having illative postposition, e.g. a friend to dogs, lit. heart into dogs); Chim -santce, heart.

Q kuku-pi, liver; Ancachs Q kukus, liver; Subt gi·ko, liver.

Q hayaqen, gall; Sal t-e'rk, animal's gall.

Q uspun, guts; Chim -pxa, guts; Sal p'xat', excrement, intestines.

###### *Privates*

Q wa-, buttocks, anus, in wa-ra, pants; Q wa-nu, manure; Chim -wi, anus.

Q tcupa, tail; Q tcutcupay, to drag behind; Q tcuta, to drag; Chim -tcxa-, to pull.

###### *Pectoral*

Q ma-ki, hand, arm; Q ma-tc'in, upper arm, upper leg; Chim -tran-pu, arm; Chim imu, to hold; Yana mô-, to reach, to hold; Pomo mi-, ma-, with the hand; Pomo ma, to hold; Sal me·'n, hand; Sal ṭ'o'puk, arm, wing; Subt nyau·, hand; Subt paxpuu, arm.

###### *Anal*

Q mexlyay, lap; Sal ma'pok, thigh.

Q tca(n)ka, leg; Q tcaki, foot; Chim -txan, leg.

Q muqo, knee; Q maki-muqo, wrist, lit. hand-knee; Chim hitxani-maxa, knee, lit. leg-knee; Pomo mōko, knee.

*Pectoral and Anal*

Q silyu, unguis; Q sily-q'uy, to scratch with the nails; Sal icele", unguis.

ANIMALS

*Low Forms*

Q kuru, worm; Q khisakuru, fuzzy caterpillar, lit. nettleworm; Chim xawin, caterpillar; Sal ck'ot, snake, worm, grub; Sub unyu·, worm.

*Insects*

Q usa, headlouse; utha, chicken-louse; Q isa, louse species; Q uru, spider; Q uru-si, spider; Pomo atcī, louse.

Q tchilyiku, cricket; Sal tc'e·l', cricket.

Q pilypintu, a small butterfly species; Atsugewi palala, butterfly; Washoe palolo, butterfly; Pomo lilawa, butterfly.

Q t'oxto, bee; Chim xōwu, yellowjacket.

*Fishes*

Q tcalywa, to fish, fish; Q tcalytcaly, to wriggle in the water as a fish does when swimming; Q tcalypu, to submerge intr.; Pomo ca, fish; Sal swan, fish; Tonkawa esva-la-n, fish.

*Amphibians*

Q q'ayra, frog species; Chim qâtus, frog; Subt kosta-lu·, frog.

*Birds*

Q tciwtci, fledgling (compare also Q tcutci, thrush); Chim tira, bird; Pomo tsita, bird; Sal ca·xwe, bird. Q tciwtci is the general term for fledgling, with which is to be contrasted Q malyqo, fuzzy fledgling.

Recuay Q watas, crow; Chim wa'la, wa'da, crow.

Q waman, falcon; Chim wemer, eagle.

*Mammals*

Q huk'u-tca, mouse, lit. inner cornerlet, from Q huk'i, inner corner; Pomo -uk, corner.

Q qowi, cuy (*Cavia aperea*) (this animal is called in Spanish cuy alias conejillo de Indias, the former having been taken over from Quechua into Spanish); Q kututu, male jackrabbit; Sal kol', hare.

Cajamarca Q tcitci, bat; Sal tc'e'mtcem, bat.

AGE-SEX

Q qhari, man in prime; Q qosa, husband; Q orqo, male; Pomo kawi, boy.

Q warmi, woman in prime; Q watca, woman (vulgar expression); Q warma, young; Q wararay, to chatter; Pomo xatai, woman.

Q tcina, female; Q tcitcu, pregnant; Chim -sa, woman.

Q wawa, child; Q wawasimi, childhood dialect; Q makipwawa, finger, lit. handlet; Yana -'alā-, child.

Q tc'ini, small; Q hutc'uy, small; Q tcuri, father's son; Chim tcitci, child; Choct uci, child; Subt tci·tci, small.

Chinchay Q tcatca, old woman; Sal tce-, old; Choct tcikki, old.

STATUS

Q masi, companion; Esselen -i'wis, friend.

KINSHIP

Q tayta, father; Q Tayta-tca, God; Sal te·le", father.

Q mama, mother; Q ma-rq'a, to carry in arms; Sal apai", mother.

Q qosa, husband (already given above).

PHENOMENA

Q aqo, sand; Q tc-'aqo, white clay; Chim ama-yāqa, sand, lit. earth sand.

Q katci, salt; Pomo kec̄, salt.

Q matcay, cave, Q matcu-la, grandfather, ancestor; Yana mu-, hole; Pomo mo, hole, cave.

Q nyan, trail; Choct hina, road.

Q pampa, n, plain, adj, flat. (that pampa means primarily flat land is shown by pampatciy, to forgive, lit. to even); Q paxra, bald, lit. smooth; Q pax-ta, perhaps; Pomo pai, a flat.

Q para, rain; Q parqo, to irrigate; Yana barī-, to rain.

Q pa-tca, the earth (that the primary meaning is the earth is shown by Q patca-phuyu, fog, lit. earth-cloud); Q patcax, 100; Pomo ma, earth; Subt u·mba, earth.

Q phosoqo, foam; Pomo phus, foam.

Q phuyu, cloud; Cajamarca Q phukuta, cloud; Sal pa·'i·', cloud.

Q qaqa, rock; Chim qā'a, stone; Yana k!ai-na, stone; Sal (t)cxa', stone.

Q qasa, cold weather; Q qhasay-ukhu, in winter; Chinchay Q qaca, cold weather; Chim xatsa, cold; Yana hātsłit'-, cold; Choct hotcukwa, cold.

Q qa, seasonal stream; Q qo-, water; Q -qe, water in wi-qe, lacrima, lit. eye-water; Chim -xa, water; Yana xa-na, water; Sal (t)ca', water.

Q rumi, stone; Q ruru, fruit pit, seed, eyeball; Q runtu, egg; Q ranra, gravel; Pomo ta, sand.

Q silya, gravel; Subt si·-nu, stone.

Q tuta, night; Chim diwe-, night; Subt m-idu·u·, night.

Q tciraw, dry season; Chim atcxumni, dry.

Q tchisi, to become night; Q tchilyu, black; Q tchi-maxlyu, night-snow; Q tc'isi, last night; Q tc'extci, gray; Chim tcĕlĕ-i, black.

Q witca, up; Q wayra, wind, aloft; Q wayq'o, valley; Q waylya, meadow; Chim wiemu, up; Chim waida, upstream, east; Yana -wasa-, above.

Q yaku, water; Pomo g'oki, to drink.

### ASTRONOMICAL

Q inti, sun; Q inka, emperor (one title of the emperor was inti-p tcuri, son of the sun); Q intu, to conquer; Q ilyay, to shine; Q lyilyi, heat-eruption; Chim alla, sun; Pomo da, sun; Sal na, sun.

Q paxsa, moon; Washoe d-i·be, luminary; Subt bii·, day.

### ABSTRACT

Q muyu, circle; Q muyuy, to circulate; Chim nolle, round.

Q sinri, line; Q siq'e, line; Q siray, to sew; Q sirk'a, vein; Q siru, net; Pomo ca-, with end or point.

Q su-ti, name; Sal a·'se, name.

### COLORS

Q puntcaw, day, daylight; Q paqar, morning; Washoe pi-, white.

### MATERIAL CULTURE

#### *Fire*

Q k'antca, fire; Q q'ontca, hearth; Q k'an, heat; Q q'onyi, hot; Q q'ilyimsa, charcoal; Q kanay, to burn; Q qhonoy, also qhanoy, to light (ceremonial fire at festival); Q kanka, a roast; Chim kōwa, coals.

Q q'osnyi, smoke; Chim qe, smoke.

Q nina, fire; Q inti, sun; Q ilyay, to shine; Yana -'lai-, to warm; Sal lo·L, to get burnt.

#### *House*

Q wa-si, house; Chinchay Q wa-hi, house; Chim a-wa, house; Chim w-issa, door, lit. house's trail.

## ADJECTIVE

### *Adjective Affixes*

Adjective affixes are partly the same as noun affixes.

### *List of Adjectives*

Q alyi, alyin, good; Choct a$^{n}$li, true, good.

Q amu, mute; Yana 'ému-, to stop crying.

Q hatun, large; Pomo m-atō, large.

Q hun-t'a, full; Q hun-t'a-q, punctual; Q hunu, a million; Yana ba'nI-, to be full; Sal ep'enāteL, to fill (plural subject).

Q nyuxnyu, sweet and soft; Q nyunyu, female breast; Q lyulyu, tender shoot of a plant, tender meat; Chim lo'or-en, soft.

Q lyusk's, slippery; Chim -klu-, to slip; Yana -lili-, to be smooth; Pomo les, to smear.

Q mosoq, new; Subt ma·ca, raw.

Q poqes, adj, fat; Yana p'uI'-, to be fat; Pomo pūi, greasy; Sal upi-nit, fat.

Q q'enqo, twisted; Chim p'qĕlĕ'-in, crooked; Sal (Sitjar) upk'i'na, to twist.

Q q'urqo, bitter; Yana k!ai-, to be bitter.

Q tchaki, dry; Q tchaka, hoarse; Chim atcxumni, dry.

## PRONOUN

### *Personal Pronoun*

Q nyo-qa, no-qa, I; Chim nō-ut, I.

Q -y, my; Chim -i, my; Sal e-, my.

Q qan, you; Sal k-, you (employed in the imperative only).

Q pay, he; Sal pa, that.

### *Demonstrative Pronoun*

Q kay, this; Chim qe, this.

Q tcay, that (by you); Pomo te·-, that; Subt ta-, that. Q tcay is the only demonstrative which is also used as a verb prefix meaning that already referred to.

### *Interrogative Pronoun*

Q ima, what?; Sal ma-s, someone; Subt ma·-na, what?

Q pi, who? Yana apbi-, who?

### *Numeric*

Q as, a little. (Q as-, slightly, as a verb prefix, has already been presented above.) Subt ax, a little.

*Numeral*

Q -puni, self; Chim p'un, 1.

Q iskay, 2; Chim xoku, 2.

Q kinsa, earlier kimsa, 3; Chim xodai, 3.

Q tawa, 4; Hokan (as reconstructed by Sapir) *axwa, 4.

*Consonant Prefixes*

Several consonant prefixes, isolated in Quechua with great difficulty, have been found, and are here presented together, since they have bearing together on connection with Salinan, one of the Hokan languages noted for development of such consonants.

Cajamarca Q qewa, plant; Q iwa, plant; Sal k-, intransitive, less commonly transitive, rarely indicative of plural subject. The presence of initial q can also be interpreted as in place of initial ', unwritten in the present paper.

Q p-ilyu, crown; Q ilya-y, to shine; Q m-alyma, earth prepared for sowing; Q halyma-y, to bank earth around a plant; Sal p-, transitive, less commonly intransitive, rarely indicative of singular subject.

Q saqe-y, to leave; Q haqe-y, to leave; Sal se-, substantive.

Q t-awa, 4; Hokan (as reconstructed by Sapir) *axwa, 4; (but compare Yana daumi-, 4); Q t-axya, ball-excrement; Q aka, excrement; Q tc-'aqo, white clay; Q aqo, sand; Sal t-, nominal.

WORD ORDER

Word order has in each one of the Hokan languages an established precedent. Initial and final positions in the sentence are the most emphatic. In Quechua the standard word order is ovs, in which o stands for objective, v for verb, s for subjective. The interrogative postfix -taq, which has been given above, is the only postfix of sentential stratum presented in this paper, and imparts interrogation to a word or to an entire sentence, a modulation which could also be executed by voice alone. Chimariko has two standard word orders: svo and sov.

RÉSUMÉ

Experience in the evaluating of Quechua words for comparison has been like that of the geologist who explores waterway cobbles. The interior of the cobbles has to be looked into and anchored before provenience is certain. As Quechua words become in the future better analyzed, their connection with Hokan forms will become more certain and standardized.

## ZOOLOGY.—*Another Mexican snake of the genus* Pliocercus.[1] HOBART M. SMITH, University of Rochester. (Communicated by HERBERT FRIEDMANN.)

Through the courtesy of the authorities of the Museum of Vertebrate Zoology, of the University of California, and particularly of Thomas Rodgers, I have had the privilege of examining and describing an interesting specimen of *Pliocercus elapoides*, which not only extends the known range of the genus northward about 300 miles from central Veracruz to central Tamaulipas and into another faunal area, but also represents a race distinct from any known previously.

**Pliocercus elapoides celatus,** n. subsp.

*Holotype.*—Mus. Vert. Zool. 24689, collected by Meldon Embury at Ciudad Victoria, Tamaulipas, Mexico, on June 31, 1937.

*Diagnosis.*—Like *P. e. elapoides*, but outer black rings of each triad on body greatly reduced, shorter than yellow rings, sometimes absent; ventrals perhaps fewer (126 in a male as compared with 128 to 131); black rings on body perhaps more numerous (12 as compared with 9 or 10) in males. Like *P. e. schmidti*, except snout uniformly black (except at lip); nuchal black collar not involving labials or parietals and covering 8 instead of 5 scale lengths on nape; and the primary black rings longer, involving 3 or 4 ventrals and 4½ or 5 dorsal scale lengths.

*Description of holotype.*—Head scales normal; portion of rostral visible from above about as long as median suture between internasals and about two-thirds the greatest length of internasals; latter two-thirds as long as broad, a little more than half as long as prefrontals; frontal pentagonal, the anterior edge forming a slight convexity, sides markedly convergent, posterior edges meeting at an acute angle;

[1] Received September 15, 1943.

frontal longer (4 mm) than its distance from tip of snout (3.3 mm) and posterior median edge of parietals (3 mm); nasal completely divided, posterior section a little larger and higher than anterior; loreal about as large as anterior section of nasal, a little longer than high; a large upper and a very small lower preocular; latter separating third labial from orbit, former widely separated from frontal; 2 postoculars, lower two-thirds size of upper; temporals 1–1–2, the anterior longest; 8–8 supralabials, the last 2 subequal in size and larger than others; 9–9 infralabials, 5 in contact with anterior chinshields, 2 with posterior, the anterior in contact medially with its mate, 6th largest; chinshields equally elongate, anterior slightly the broader; posterior chinshields in contact for about half their length; 2 small scales between chinshields and 1st ventral.

Dorsal scales smooth, pitless, in 17–17–17 rows; ventrals 126; tail tip missing; anal divided; snout-vent length 230 mm; male.

Black head cap extending posteriorly to tip of frontal and anterior tips of parietals, uniform on snout except near lip, extending laterally to about the middle of the first 5 infralabials; edge of entire upper lip light; a light collar following this, presumably yellow in life; a black nape collar involving tips of ventrals, occupying 8 scale lengths dorsally, and involving extreme posterior tips of parietals, the posterior parts of the tertiary temporals, but not the labials. Eleven other, similar dark bands on body, all complete, involving 3 or 4 scale lengths ventrally and 4½ or 5 dorsally, separated from each other by areas about equal to or a little greater than their length. A narrow light ring bordering each black ring, occupying little more than one-half of 1 scale length. Between the yellow rings are red bands in which most of the dorsal scales are black-tipped; this black spotting is usually, but not invariably, more concentrated next to the yellow bands, thus forming the effect of secondary black rings; these secondary rings are indistinct, however, narrower than the yellow rings, and sometimes not evident. On the tail the pattern is much the same, except that the secondary black rings are more distinct. In no place do the secondary black rings extend onto the ventral surface. The belly and subcaudal surfaces are unpigmented except for the primary black rings; the chin and lower labial regions are also immaculate. The red rings are evident ventrally, however.

*Remarks.*—This specimen is markedly different from *e. elapoides*, the nearest race geographically, particularly in the reduction of the secondary black rings (see diagnosis). It resembles *e. schmidti* more than any other race, but in addition to being geographically distant has narrower primary black rings and a mottled snout; *e. schmidti* and *e. celatus* may be considered either as parallelisms or as slightly differentiated forms of a more primitive and more widely distributed stock. The latter alternative appears the more attractive, for although *e. elapoides* is centrally situated between the other two races, its pattern is relatively highly specialized and is subject to frequent bizarre variation. *P. e. laticollaris* is another slightly differentiated form similar to *e. schmidti* and *e. celatus*, but having incomplete black rings and more numerous infralabials.

With the addition of the present race to the list of known forms, it is of considerable interest to observe that every biotic province on the Atlantic coast of Mexico is now represented by its distinctive race of *P. elapoides*. While the details of the distribution of the four Atlantic races in Mexico are not known, a strong correlation with the four corresponding provinces is indicated, although a certain amount of discrepancy in exact boundary lines of races and provinces is to be expected. Although the east coast subspecies of *P. elapoides* are now perhaps completely outlined, at least with no further additions to be anticipated, the races of the Pacific coastal regions are very poorly known. That two or three races remain to be discovered and defined in that region is highly probable. Whereas eight species and subspecies of *Pliocercus* are now known from Mexico, about 11 are to be expected, and, of course, more may occur.

# PALEONTOLOGY.—*Identification of* Actinocrinus chloris *Hall.*[1]

EDWIN KIRK, U. S. Geological Survey.

Wachsmuth and Springer (1881, p. 146 (320), and 1897, p. 571) cite McChesney's species *Actinocrinus tenuisculptus* and place *A. chloris* Hall in synonymy with it. This precedent has generally been followed by authors. It turns out that the two species are quite distinct and indeed referable to different genera. My attention was called to this case of mistaken identity while checking over some of McChesney's species. It was obvious that the specimen figured by McChesney, if accurately drawn, could not be the species figured by Wachsmuth and Springer (1897, pl. 55, figs. 4a, b). Fortunately, I found in the U. S. National Museum a sulphur cast of the holotype of *A. tenuisculptus* made by Whitfield, which agrees with McChesney's illustration. The type itself was destroyed in the Chicago Fire. I had long known the beautiful little species identified by Wachsmuth and Springer as *A. tenuisculptus*. The identity of the *"A. tenuisculptus"* of Wachsmuth and Springer (1897) was established by the fortunate discovery of the cotypes of *A. chloris* Hall in the portion of the White collection acquired by Springer from the University of Michigan. The species has never been figured, and its identity has never been recognized. It proves to be the form erroneously identified by Wachsmuth and Springer as *A. tenuisculptus*. The following citations will correct the synonymy:

**Actinocrinus chloris** Hall

*Actinocrinus chloris* Hall, 1861a, p. 3; 1861b, p. 275. "Burlington limestone, Burlington, Iowa. Collection of C. A. White." (Lower Burlington.)

= *Actinocrinus tenuisculptus* Wachsmuth and Springer (not McChesney), 1897, p. 571, pl. 55, figs. 4a, b.—Moore and Laudon, 1943, pl. 10, fig. 11.

The cotypes of *Actinocrinus chloris* Hall are two specimens in the Springer collection in the U. S. National Museum numbered S 1142. One is an imperfect dorsal cup. The other is a somewhat crushed theca. There can be no question as to their identity, thanks mainly to the distinctive character of the species.

Many of the crinoids described by Hall, Meek and Worthen, and others in the early days are based on badly preserved specimens, and a minimum amount of time was spent preparing them. There was such intense rivalry in describing new species that a name was attached to almost any specimen found, however imperfect. When figured the specimen took on a more passable aspect, owing to the kind ministrations of the draftsman. Wachsmuth was the first to be sedulous in collecting good crinoids and spent days in preparing them.

**Cactocrinus tenuisculptus** (McChesney), n. comb.

*Actinocrinus tenuisculptus* McChesney, 1860, p. 15, pl. diagram p. 17 ("Burlington division of the Carboniferous limestone series, Columbia, Missouri"); 1865, pl. 5, figs. 1a, b; 1868, p. 11, pl. diagram p. 12, pl. 5, figs. 1a, b.

Not *Actinocrinus tenuisculptus* (= *Actinocrinus chloris* Hall) Wachsmuth and Springer, 1897, p. 571, pl. 55, figs. 4a, b.—Moore and Laudon, 1943, pl. 10, fig. 11.

This species is referred to *Cactocrinus*. With equal propriety it could be referred to *Teleiocrinus*. In a species such as this the decision as to generic assignment must be arbitrary. It is placed in *Cactocrinus* because it more nearly resembles some species referred to that genus than any species referred to *Teleiocrinus*.

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[1] Published by permission of the Director, Geological Survey, U. S. Department of the Interior. Received July 9, 1943.

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# PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

## GEOLOGICAL SOCIETY

### 601ST MEETING

The 601st meeting was held at the Cosmos Club, January 14, 1942, President C. S. Ross presiding.

*Informal communications*—J. B. MERTIE, JR., spoke on nomograms of formulae on optical properties of minerals.

*Program*—W. T. PECORA and S. W. HOBBS: *Geology of the Nickel silicate deposit near Riddle, Oregon.*

W. G. PIERCE: *Heart Mountain and South Fork thrusts, Wyoming.* The Heart Mountain thrust sheet of northeastern Wyoming is traceable from Clark Fork Valley southward beyond the South Fork of Shoshone River. If it continues still farther southward into the northwestern part of the Wind River Basin, as appears possible, its linear extent is more than 90 miles.

The South Fork thrust is beneath, and is older than, the Heart Mountain thrust. A troughlike fold of the South Fork thrust sheet, which appears to have been downfolded after the thrusting, lies in the valley of the South Fork of the Shoshone River. The rocks in the trough have been folded into a syncline, and a recumbent anticline presumably formed during the emplacement of the thrust. Northeastward from the South Fork of the Shoshone, the thrust extends as a low-angle fault into the Shoshone Reservoir, where it is thought that the inclination and trend change abruptly, and that the fault thence continues to the northwest up Rattlesnake Valley as a high-angle shear fault.

The Heart Mountain thrust probably was not shoved eastward for a distance of many miles by a pressure applied at the western edge of the thrust. The active compressional force that produced the thrust may have been directed westward as an underthrust.

It seems doubtful if the western source of the Heart Mountain thrust extends down into the crystalline basement, for throughout its known east-west extent of 35 miles there are no rocks older than the Ordovician Bighorn dolomite in the thrust sheet. Likewise the South Fork thrust probably does not extend below the Sundance formation of Jurassic age, for, although this formation commonly floors the thrust, there are no older rocks anywhere in the thrust.

The emplacement of the South Fork thrust followed the deposition of early Wasatch strata. The emplacement of the Heart Mountain thrust followed the deposition of later Wasatch strata, and after partial erosion of the thrust sheet the "early basic breccia" of the region were deposited.

Vertebrate fossils indicate that the Heart Mountain thrust was emplaced near the close of the lower Eocene. The South Fork thrust was formed some time earlier in the Eocene. (*Author's abstract.*)

F. E. MATTHES: *Glacial events of the historic period.* Fairly complete records exist of the major advances and recessions that the glaciers in the European Alps have experienced during historic times. These records show that toward the end of the sixteenth century climatic conditions grew more severe than they had been during the Middle Ages, and the glaciers gained considerably in length and volume. Alpine villages that had prospered for centuries were overwhelmed by advancing glaciers, or rendered uninhabitable by torrents of melt water; and such catastrophes occurred repeatedly during the first half of the seventeenth century. Other periods of marked glacier expansion were chronicled in 1680, 1719, 1743, and 1770. The last notable glacier advances took place in 1820

and 1850. All these advances were of about the same magnitude, but most of them fell short of the limits reached by those of the early 1600's. Since 1855 recession has been dominant, and since 1920 it has proceeded at an accelerated rate.

From comparative studies of the moraines in the Alps it is clear that the historic glacier advances have been by far the greatest that have occurred since the Pleistocene ice age. The moraines in Norway and Iceland tell a similar story. These facts, taken together with the abundant evidence that is now at hand that great warmth prevailed during the middle part of postglacial time, warrant the view, it is believed, that the historic period had been, in effect, a period of moderate reglaciation—a "little ice age," as a clever journalist has called it.

### 602D MEETING

The 602d meeting was held at the Cosmos Club, January 28, 1942, President C. S. Ross presiding.

*Informal communications*—H. D. MISER spoke on the Red River Dam near Denison, Tex.

*Program*—E. B. ECKEL: *Geology of the New Idria District, California.*

EUGENE CALLAGHAN: *Some features of tin, tungsten, and antimony deposits of Bolivia.*

ROBERT E. ALLEN: *The oil outlook in this war.*

### 603D MEETING

The 603d meeting was held at the Cosmos Club, February 11, 1942, President C. S. Ross presiding.

*Program*—W. C. ALDEN: *Cirques, hanging valleys, and high-level benches of Glacier National Park.*

WALTER H. BUCHER: *Method proposed to introduce a concept of "limits of error" into the stratigraphic timing of tectonic movements.*

### 604TH MEETING

The 604th meeting was held at the Cosmos Club, February 25, 1942, President C. S. Ross presiding.

*Informal communications*—EARL INGERSON spoke on measurements of linear elements in the field.

*Program*—J. B. MERTIE, JR., and R. R. COATS: *Tin deposits of Seward Peninsula, Alaska.*

R. N. JAHNS: *Sheet structure in granites; its origin and use as a measure of glacial erosion in New England.* Sheet structure in New England granites consists of lenticular, flat to gently curved exfoliation shells that tend toward parallelism with the exposed rock surface. In general they become progressively thicker, flatter, and more regular with increasing depth, and they have been observed at and near the bottoms of the deepest quarries. Sheeting is completely independent of all primary structures in the rock and commonly transects contacts between the granite and xenoliths, roof pendants, the country rock itself, and minor postgranite intrusive bodies. Evaluation of the possible causes of sheet structure in the light of present available data indicates that the release, through removal of superincumbent load, of a primary confining pressure to which the rock has become adjusted is chiefly responsible for the large-scale exfoliation phenomena involved. Insolation, the progressive hydration and formation of chemical alteration products in certain susceptible minerals, and the mechanical action of fire, frost, and vegetation are possible minor contributory causes.

With very few exceptions the sheet structure on the granite hills of northeastern Massachusetts and adjacent parts of New Hampshire, where detailed studies have been made, is preglacial in origin. Its attitude with respect to present topography therefore facilitates certain comparisons with preglacial topography, and thus permits minimum estimates of the thickness of material removed by glacial ice from specific localities. Cross sections that show the critical relations have been constructed for several typical hills.

The minimum depth of glacial erosion can also be estimated by a second, less direct method. Not only do the granite sheets or shells thicken with depth, but statistical data demonstrate a fair degree of quantitative consistency in this relation. The sizes of large granite boulders—and therefore of the respective sheets from which they were torn by the ice—thus furnish an additional clue to their original depth beneath the pre-glacial surface. Results of studies by the above methods suggest the removal of a blanket of rock and preglacial regolith at least 10 to 15 feet thick by glacial abrasion and plucking from the stoss, or north slopes of most hills, and of a somewhat greater thickness from their east slopes, summits and west slopes. Severe plucking and quarrying of jointed rock

appears to have been responsible for strongly concentrated erosion on the lee, or south and southeast slopes of many hills to maximum demonstrable depths in excess of 100 feet.

CHESTER R. LONGWELL: *Some structural features in southern Nevada.*

### 605TH MEETING

The 605th meeting was held at the Cosmos Club, March 11, 1942, President C. S. Ross presiding.

*Program.*—R. L. NICHOLS: *Flying bars in Boston Harbor.*

R. P. FISCHER: *The vanadium deposits of Colorado and Utah.* Deposits of carnotite and vanadium-bearing sandstone are widely distributed in western Colorado and eastern Utah and have been the principal domestic source of vanadium, uranium, and radium. At present these deposits are being intensively mined for vanadium. Most of the deposits are in the Morrison formation, but there are some in the Entrada sandstone and the Shinarump conglomerate.

Recent X-ray studies by Sterling Hendricks of the Department of Agriculture indicate that the principal vanadium mineral, heretofore considered to be roscoelite, belongs to the hydrous mica group of clay minerals. This mineral impregnates the sandstone, coating sand grains and partly or completely filling interstitial spaces between the grains. Shale pebbles and finely divided "mud" material in the ore-bearing sandstone are rich in absorbed vanadium. Carnotite and other vanadium minerals are found in some of the fossil plant material associated with the ore. The vanadium-bearing hydrous mica is in part rather uniformly disseminated through the sandstone and in part concentrated along bedding planes or in thin zones that cut across bedding. Because these zones form curved or undulant planes, they are called "rolls" by the miners. Where the sandstone was strongly mineralized, as along the favorable bedding planes or along the rolls, the grains of quartz sand have been partly dissolved, resulting in a small decrease in volume of the mineralized sandstone and causing minor "slumping," which is evident where the rolls cut across the bedding at a moderate angle.

Ore bodies are irregularly tabular masses which lie essentially parallel to the sandstone beds, but the ore does not follow the beds in detail. The trend of elongate bodies is indicated by the orientation of the rolls within the ore, and this trend also suggests the probable alignment of any adjacent bodies.

No satisfactory explanation can yet be offered for the origin of these deposits. The ore bodies appear not to have been localized by such geologic structure as fractures or folds, but within limited areas they are restricted to certain stratigraphic zones.

LOUIS MCCABE: *Application of a nes petrographical method to the study of coal.*

### 606TH MEETING

The 606th meeting was held at the Cosmos Club, March 25, 1942, President C. S. Ross presiding.

*Program.*—W. C. ALDEN: *Some aspects of the geology of Glacier National Park.*

P. D. TRASK: *Some ideas on the origin of northern California manganese deposits.*

N. W. BASS: *Relationship of crude oil to stratigraphy.*

### 607TH MEETING

The 607th meeting was held at the Cosmos Club, April 8, 1942, President C. S. Ross presiding.

*Informal communications.*—H. D. MISER spoke on the use of a common geophysical instrument for afternoon field parties.

*Program.*—J. PEOPLES: *Some features of the chromite of the Stillwater Complex, Montana.*

R. E. STEVENS: *Composition of some chromites of the Western Hemisphere.*

T. A. HENDRICKS: *A cold spring manganese deposit in North Dakota.*

### 608TH MEETING

The 608th meeting was held at the Cosmos Club, April 22, 1942, President C. S. Ross presiding.

*Informal communications.*—H. C. SPICER demonstrated an A. C. microchemical heater.

J. S. WILLIAMS presented lantern slides of an Alaskan glacier surface.

*Program.*—W. M. CADY: *Quicksilver deposits of Sleitmut, Georgetown District, southwestern Alaska.*

G. A. COOPER: *Silicified fossils and their significance.*

D. F. HEWETT: *The Morro da Mina mine, Brazil.*

### 609TH MEETING

The 609th meeting was held at the Cosmos Club, November 11, 1942, President C. S. Ross presiding.

*Program.*—R. W. IMLAY: *Jurassic formations of the Gulf region.*

CHARLES MILTON and JACK MURATA: *The occurrence of Weinschenkite in Virginia.*

L. G. HENBEST: *Sandstone dikes near Salida, Colorado.*

### 610TH MEETING

The 610th meeting was held at the Cosmos Club, November 25, 1942, President C. S. Ross presiding. President Ross announced the death of Dr. HERMAN STABLER, of the U. S. Geological Survey.

*Program.*—MICHAEL FLEISCHER and W. E. RICHMOND: *Mineralogy of the manganese oxides.*

W. S. TWENHOFEL: *A molybdenite deposit in the Glacier Bay area, southeastern Alaska.*

JOHN W. FREY: *Oil in the mind.*

### 611TH MEETING

The 611th meeting was held at the Cosmos Club, December 9, 1942, Vice-President CURRIER presiding.

C. S. Ross presented his presidential address, *Clays and soils in relation to geologic processes*, published in this JOURNAL 33 (8): 225–235. 1943.

### 50TH ANNUAL MEETING

The 50th annual meeting was held at the Cosmos Club after the adjournment of the 611th regular meeting, Vice-President CURRIER presiding. The annual reports of the Secretaries, Treasurer, and Auditing Committee were read and approved.

The results of balloting for officers for the ensuing year were as follows: *President:* HERBERT INSLEY; *Vice-Presidents:* W. H. BRADLEY and GEORGE TUNELL; *Treasurer:* K. J. MURATA; *Secretaries:* J. J. FAHEY and K. E. LOHMAN; *Members at large of the Council:* R. S. CANNON, L. W. CURRIER, M. D. FOSTER, E. N. GODDARD, and E. F. OSBORN; *Nominee as Vice-President of the Washington Academy of Sciences representing the Geological Society:* C. S. ROSS.

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MEMORIAL TO MISS OLIVE C. POSTLEY, READ BEFORE THE GEOLOGICAL SOCIETY OF WASHINGTON BY H. D. MISER, MARCH 26, 1941.

OLIVE C. POSTLEY, a member of this Society for the past 20 years, died at Emergency Hospital in Washington on January 14, 1941. She was born in Washington, the daughter of Dr. Charles E. and Clara M. Postley. She acquired her professional training at George Washington University, where her major subject was geology. Early in life she joined the staff of the Geological Survey as a clerk and devoted herself to varied and responsible duties in that organization. In 1926 she qualified under the Civil Service as junior geologist, and in 1931 was advanced to assistant geologist. She served most efficiently as assistant to the chief geologist for a period of almost 30 years—during the administrations of David White, W. C. Mendenhall, T. W. Stanton, and G. F. Loughlin. Her capacity for accomplishment merited and received continued recognition and advancement.

Miss Postley, besides serving as the chief geologist's assistant, handled personally a great volume of direct and written inquiries to the Survey about the oil, gas, and coal resources and the geology of the United States. She made occasional field studies, chiefly under David White's guidance, in Pennsylvania, West Virginia, and Virginia, and through wide travel elsewhere in the United States acquired much personal knowledge of the geology of the country. Her knowledge of oil and gas is indicated in her publications, which include several papers on the oil and gas geology of the United States, and maps showing the oil and gas fields in Louisiana and Kansas. The Kansas map is unique in that it shows the geologic ages of the producing formations in the fields. It is the first oil and gas map of this type that the Geological Survey has issued. The Survey's recently published oil and gas map of the United States bears Miss Postley's name as a joint author.

In recognition of her work in petroleum geology she was elected in 1926 to membership in the American Association of Petroleum Geologists.

As an individual Miss Postley was vivid and eager, absorbed in the adventure of life, and alert to all that it had to offer. She was instantly responsive to friendliness; her generosity, unselfish and untiring devotion to others, and intense loyalty were among her outstanding characteristics. Her energy and enthusiasm outran her strength and continued to the end—perhaps hastened that end. Thus a great void is left in her personal circle, and the Society has lost an energetic member.

# Obituaries

MARY JANE RATHBUN, an original member of the Academy, died at her home in Washington, D. C., on April 4, 1943, in her eighty-third year. She was born in Buffalo, N. Y., on June 11, 1860. What she knew of zoology she learned largely through her own efforts and powers of observation. Educated in the public schools of Buffalo, where she was graduated from the Central High School in 1880, she majored in English and received a gold medal for excellence in that subject. To her thorough knowledge of the English language she attributed a great deal of her success in later life. This mastery of English is reflected throughout her extensive correspondence with zoologists in this country and abroad and in her many published works.

The first time she ever beheld the ocean was in 1881, when she accompanied her brother Richard, later the director of the U. S. National Museum, to Woods Hole. She often remarked that it truly opened up to her a whole new world, and from that time on she devoted herself largely to studies of marine life.

Her first employment was wholly on a voluntary basis with the old U. S. Fish Commission, with which she spent the summers at Woods Hole from 1881 to 1884, when she was appointed to a clerkship with a very modest stipend. As Spencer F. Baird in those days was both Secretary of the Smithsonian Institution and the head of the Fish Commission, which he founded, it was but a step from one organization to the other. In 1886 Miss Rathbun was appointed copyist in the division of marine invertebrates of the National Museum, where her duties as record-keeper and cataloger brought her into intimate contact with the veritable flood of marine life which descended upon the Museum as the result of the intensive investigations of fisheries and aquatic resources of the United States in which the Commission was pioneering at that time. The beautifully written specimen labels and catalogue entries in her clear, flowing Spencerian hand have never been equaled for clarity and legibility, and today they form the backbone of the records of the division of marine invertebrates. She was one of the first to use that early block-letter typewriting machine known as the Caligraph. The station data and accession lists of the once famous and still valuable Gloucester Fisheries Donations which she ran off on that machine are still in use.

Very early in her career Miss Rathbun became interested in the decapod Crustacea, and almost without exception they form the subject matter of her 158 published works. The first of these was a study dealing with the genus *Panopeus*, published jointly with Dr. James E. Benedict, her superior officer in the division of marine invertebrates at the time. The last was a monograph of the oxystomatous and allied crabs of America, published by the U. S. National Museum.

Included in her bibliography are a number of truly monumental accounts of marine and fresh-water crabs. The Paris Museum published her treatise on the fresh-water crabs as *Descriptions de nouvelles espèces de crabes d'eau douce appartenant aux collections du Muséum d'Histoire Naturelle de Paris*, Bull. Mus. Hist. Nat. [Paris], no. 2, 1897. The U. S. National Museum issued her four monographic bulletins dealing with marine crabs as follows: *The grapsoid crabs of America*, Bulletin 97, 1918; *The spider crabs of America*, Bulletin 129, 1925; *The cancroid crabs of America*, Bulletin 152, 1930; and *The oxystomatous and allied crabs of America*, Bulletin 166, 1937. Two other notable papers dealt with fossil crabs. The first, on *The fossil stalk-eyed Crustacea of the Pacific slope of North America*, was published as U. S. National Museum Bulletin 138, 1926; and the second was issued as Special Paper No. 2 of the Geological Society of America, entitled *Fossil Crustacea of the Atlantic and Gulf Coastal Plain*, 1935.

In 1916 she received an honorary M.A. from the University of Pittsburgh, and in 1917 her doctorate from the George Washington University.

In 1914 Miss Rathbun relinquished her salary and title as assistant curator in charge of the marine invertebrate collections, in order that the money so saved might be devoted to the hire of an assistant to ease the burden of routine falling to that much understaffed division. She continued her research work, however, as associate in zoology, and in the 25 years that followed before her retirement from

full-time active work in the Museum some 80-odd of her total 158 papers were completed. Such personal sacrifice and devotion to science, and to the institution which gave her her opportunity of pursuing the studies to which she had dedicated her life, are seldom encountered in this world.

During her lifetime Miss Rathbun gave the Museum her extensive carcinological library and at her death bequeathed the Smithsonian Institution $10,000 to further the work on decapod Crustacea in which she never lost interest and in which many another student became interested because of her works and personal encouragement.

WALDO L. SCHMITT.

With the death of CHARLES SCHUCHERT of Yale on November 20, 1942, geology lost one of its most eminent and most devoted students. Professor Schuchert was born on July 3, 1858, in Cincinnati, Ohio, where he lived for about one-third of his long life. He was educated in the public schools there but never had the advantages of a university education. Like several other noted geologists from Cincinnati, Schuchert became interested in the geology and fossils for which that region is noted. His leisure and spare time from his trade of cabinet making were spent in collecting and studying these fossils. The Schuchert collection of brachiopods attracted the attention of Prof. James Hall, of Albany, N. Y., who invited Schuchert, then 30 years old, to become his assistant. In Albany Schuchert came under the influence of J. M. Clarke and C. E. Beecher, and under these incomparable mentors his education in paleontology was completed.

After leaving the influence of the great Albany school, Schuchert started his practice of paleontology and geology with the Minnesota Geological Survey. Then he became assistant to C. E. Beecher at Yale for one year. From Yale he went to the U. S. Geological Survey for a short term and in 1894 became assistant curator of paleontology at the U. S. National Museum. There he served for ten years, leaving in 1904 to become professor of historical geology and curator of geology of Peabody Museum at Yale on the death of C. E. Beecher. In these capacities he served until 1923, when he relinquished the curatorship at the Museum. In 1926 he became professor emeritus and retained this title until his death in 1942.

At Yale Schuchert taught many graduate students and carried on numerous researches in paleontology and historical geology. His most important contributions to the latter are contained in his writings on paleogeography and paleoclimatology which he, more than anyone else, has made into a fascinating story. In paleontology Schuchert made contributions to our knowledge of many groups of fossils. His first love among the invertebrates was the brachiopods, and he devoted much time and considerable money to accumulating the fine Schuchert collection of brachiopods now at Yale. In stratigraphy he made contributions to our knowledge of the Devonian and Silurian periods, but in later years his interest turned to the Permian period. He died a few weeks before the appearance of the second volume of his ambitious *Historical Geology of North America*.

Schuchert served geology and Yale with single-minded devotion. As he once expressed it to the writer, he "married the science" and gave his whole life and much of his wealth to the welfare of his abstract mate. Having no immediate family with its drain on his time and pocketbook, Schuchert devoted himself to research, writing, and collecting. His salary and revenue from books were largely spent on geology and the field work of many deserving graduate students. His writings include more than 200 titles covering stratigraphy, paleontology, historical geology texts, and biographical sketches and memoirs.

Professor Schuchert was very generous and encouraging to the young men. In his later years his mellow philosophy and kindly interest strengthened and comforted many struggling students. Schuchert will long be revered for these qualities as well as for his devotion to geology, a devotion that helped him surmount the difficulties of early poverty and lack of training and led him to the foremost professorship of historical geology.

Professor Schuchert received many honors: the Hayden and Thompson Gold Medals of the National Academy and the Penrose Medal of the Geological Society of America. He received an LL.D. degree from New York University (1914) and the honorary Sc.D. from Yale (1930) and Harvard (1935).

G. A. COOPER.